A SYSTEM FOR MONITORING AND MAINTAINING QUALITY OF GRAIN IN STORAGE*

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Introduction

Considerable efforts have been made to increase food supplies to meet the needs of a growing world population. However, only during the last 10 years has there been the realization, on a broad scale, that we need to increase our efforts to minimize postharvest food loss as a means of increasing the total available food supply. This has been documented by the emphasis placed on postharvest losses at the World Food Conference held in Rome, 1974 (FAO, 1975). Since the late 1940's, a variety of loss estimates have been published which have ranged from a very low percentage in developed countries to as high as 50% in developing countries (Milner et al., 1978). Data in the literature are based on surveys carried out either on a large scale over a limited time period, or on studies of specific situations where losses occurred. Much of the data may be obsolete today due to the dynamic changes that are taking place in postharvest conservation technology.

In developing countries, 70 to 90% of the cereal grains produced are stored and consumed on the farm. Central storage in these countries is commonly operated by the government. The Asian Productivity Organization member countries in 1968 reported that 5 to 10% of all food grains produced were lost during storage and distribution (Pedersen, 1978). In Australia, where the largest portions of grains marketed are controlled by the government, yearly estimates of losses ranging from 0.14% to 0.68% have been reported over a 10-year period (Bourne, 1976). In grain-exporting countries, efforts are made to achieve complete control of insects during storage and before shipment of the commodities. However, in developing or grain importing countries, preservation of commodities free of infestation is dependent on the standards of living and the economics involved. It is necessary to know what losses occur in the postharvest system before efforts are initiated to reduce losses which will require the expenditure of capital.

The system for monitoring and maintaining the quality of grain in storage which will be described here was adopted following a study of stored grain losses conducted in Israel in the 1950's. The work revealed annual grain losses ranging from 10% to 20%. The system described here was originally developed by Prof. M. Calderon in Israel.

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Components of the System

1. The Authorities and Flow of Information Between Them.

Although the term "grain" in this paper generally refers to cereal grains, it also includes soybeans. Grain is marketed and controlled by the Israel government through the Ministry of Commerce and Industry (MCI), which is responsible for grain supply. Locally grown wheat is sold to the government and there is little on-farm storage. All commodities discussed in this paper are stored in bulk. Storage facilities are owned by private companies and are leased to the MCI. A private company, the General Superintendence Company (GESCO), is in charge of surveillance for quantity and quality at receipt and delivery. The grain inspection section in the Department of Stored Products (DSP) of the Agricultural Research Organization (Ministry of Agriculture) provides the professional expertise and undertakes the actual grain inspection procedure. Figure 1 shows the flow of information between the different authorities. Members of the DSP inspection section are not regulatory officials and they cannot enforce their recommendations. However, the elevator operators and grain handlers are urged to follow advice for recommended treatments after approval by the MCI. Grain condition and recommended treatments are simultaneously reported to the MCI and the GESCO. Pest control contractors, when contracted for application of chemical treatments, coordinate their treatments with the elevator operators.

The inspection team is in direct contact with the research staff of the DSP laboratory. Professional assistance is provided by the Department's Laboratory if needed. The exchange of information between the inspection team and the laboratory enables both parties to focus on problems which need investigation.

2. Inspected Commodities and Storage System.

Some 1.9 million tonnes of cereals and 430,000 tonnes of soybeans are consumed annually in Israel (Anon., 1982). The inspection team plays an important role in maintaining the grain quality after the receipt of locally grown wheat and imported cereals, including soybeans, up to the time of delivery of these commodities for processing. The grain flow diagram shows (Fig. 2) different stages of grain handling, where grain is examined by the inspection team for quality preservation. Upon request, farm storage facilities are examined and farmers are given assistance in preparing their facilities for the new harvest. During the harvest, wheat may arrive directly from the field or after pre-cleaning on the farm. After the grain is sampled at the receiving stations it is stored either in central or in temporary storages. Commodities imported by ship are inspected on-board and then conveyed through a terminal elevator to central storage facilities. Periodic inspection continues until the commodities are delivered for processing or declared to be in the possession of flour mills, feed mills or oil extraction plants.

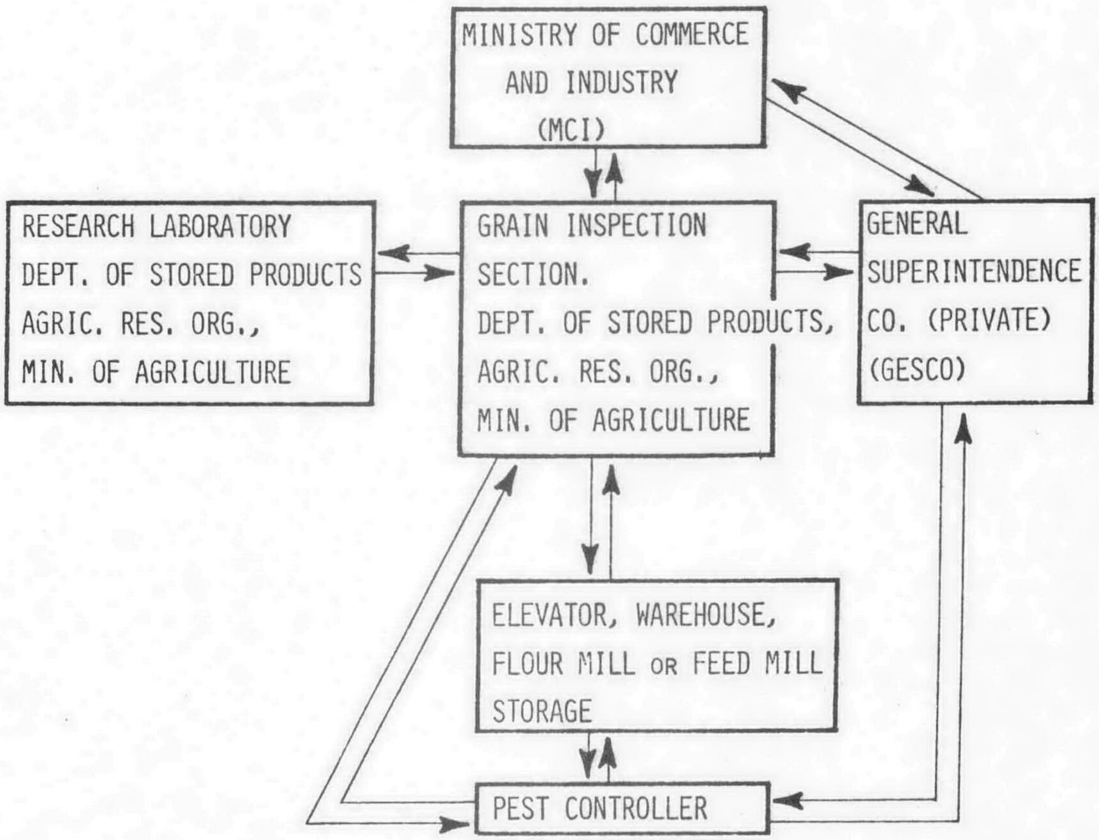

Fig. 1 - Interrelationships between bodies involved in grain handling and conservation in Israel.

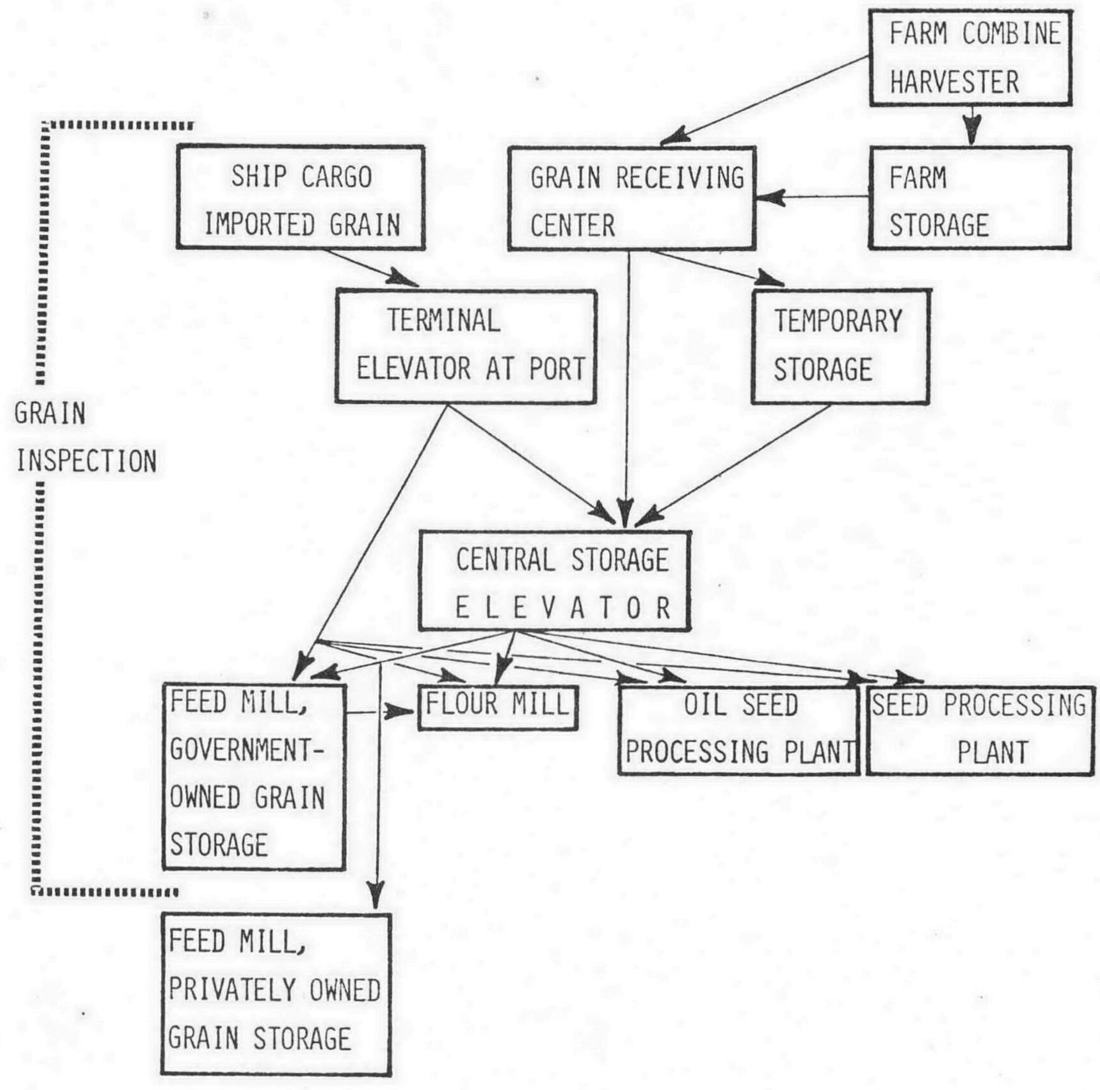

Fig. 2 - Commodity flow diagram showing different stages of storage. The active involvement of inspection is marked by a dotted line.

Inspection Procedures

1. Initial basic information on storage facilities.

This information is required for classification and identification of the facilities used for grain storage. It is updated once a year and consists of records on storage capacity for each bin, the construction material (concrete/metal), available handling facilities, storage method, aeration system airflow rate, position of temperature control systems, gas-tightness, and methods for application of chemical treatments.

2. Upon receipt of commodities.

2.1. Ship holds are inspected on-board, examined for in-transit water penetration, temperature is measured, and at this time grain samples are taken. These samples are examined for insect infestation and grain moisture content is determined. Mycotoxins and insecticide residues are examined only on request, or in suspect commodities.

2.2. Locally grown wheat is sampled at grain receiving stations by GESCO. Samples taken from each truck-load are examined for initial insect infestation by GESCO inspectors, and after sample incubation for 6 weeks by the DSP inspection team. This information is used by the MCI to credit farmers for supplying clean grain. The prices for clean and infested wheat are determined annually by agreement between the MCI and the Grain Growers Association, which represents the farmers. At this point, the inspection team is responsible for the assessment of possible damage caused by the supply of initial on-farm infested grain to the central storage facilities.

3. Regular monthly visits to storage facilities

3.1. Inspection of temporary storages. Grain after harvest may be stored in the open (on asphalt paving), in plastic silos (Navarro and Donahaye, 1976) or in converted warehouses. The plastic silos and the converted warehouses can be equipped with aeration systems and their use for storage may be extended up to a year. These storage facilities are sampled and their temperature is measured each month.

3.2. Inspection of permanent storages. All storage facilities are equipped with aeration systems and bin capacities vary from 250 tonnes to 3000 tonnes, the majority being within the range of 500 to 1000 tonnes.

The DSP inspection team examines the general appearance of the storage site and its level of cleanliness. Information recorded includes quantities in storage, recent treatments, and number of hours that the aeration system has operated.

Each bin is inspected and the temperature of the commodity is measured. Grain samples are brought to the laboratory for determination of moisture content and analysis for insect presence.

4. Preparation of weekly reports

These reports include information on infestation levels and temperature of the bulk, with indication of commodities undergoing heating and the location of the inspected bins. The same reports include recommended treatments, such as improved sanitation requirements, ambient air or refrigerated air aeration, and/or the use of insecticides, including spot or total fumigation. In addition, the efficacy of the treatment prior to the last visit to the facility is evaluated.

Analysis of Information

The information gathered by the DSP inspection team is programmed for computer analysis. This analysis of data is necessary to enable:

a. Precise definition of problems encountered in storage;
b. Evaluation of the influence of new techniques to protect quality;
c. Classification of the efficiency of each storage facility in the maintenance of grain quality;
d. Collection of data for further research designed to maintain grain quality; and
e. Construction of a simulation model to predict storability of grain at the lowest possible cost.

Some examples of this type of data, which were collected during the period from April 1980 to March 1981, are given in the following.

1. Storage temperature of commodities

The mean temperatures of locally grown wheat and imported wheat are compared in Fig. 3. The significant difference in temperatures observed from June onwards between the two wheat varieties may be attributed to the harvest time (late May - June) when most of the locally grown wheat is brought to storage at high temperatures. However, from September on, temperatures of both wheat varieties gradually decreased under the influence of aeration. Figure 3 also shows that the major portion of wheat held in different types of storage for a period of 4 to 5 months could be stored in temperatures lower than 20°C, thus reducing dependence on chemicals for insect control (Navarro, 1974).

Soybeans are sensitive to excessive moisture. Since most of the imported soybeans have an average moisture content of 13.0% (Bulbul *et al*., 1981), heating and formation of hot-spots are common problems, especially during the summer. Therefore, it is recommended that soybeans be stored in facilities equipped with refrigerated air aeration systems (Navarro *et al*., 1973).

The mean, maximum and minimum temperatures recorded on all soybeans stored over a 1-year period (1980-81) are shown in Fig. 4. Temperatures as low as from 15° to 20°C were recorded over 9 months and mean temperatures below 20°C were recorded for 5 months. For soybeans undergoing heating, maximum temperatures were recorded during September (45°C).

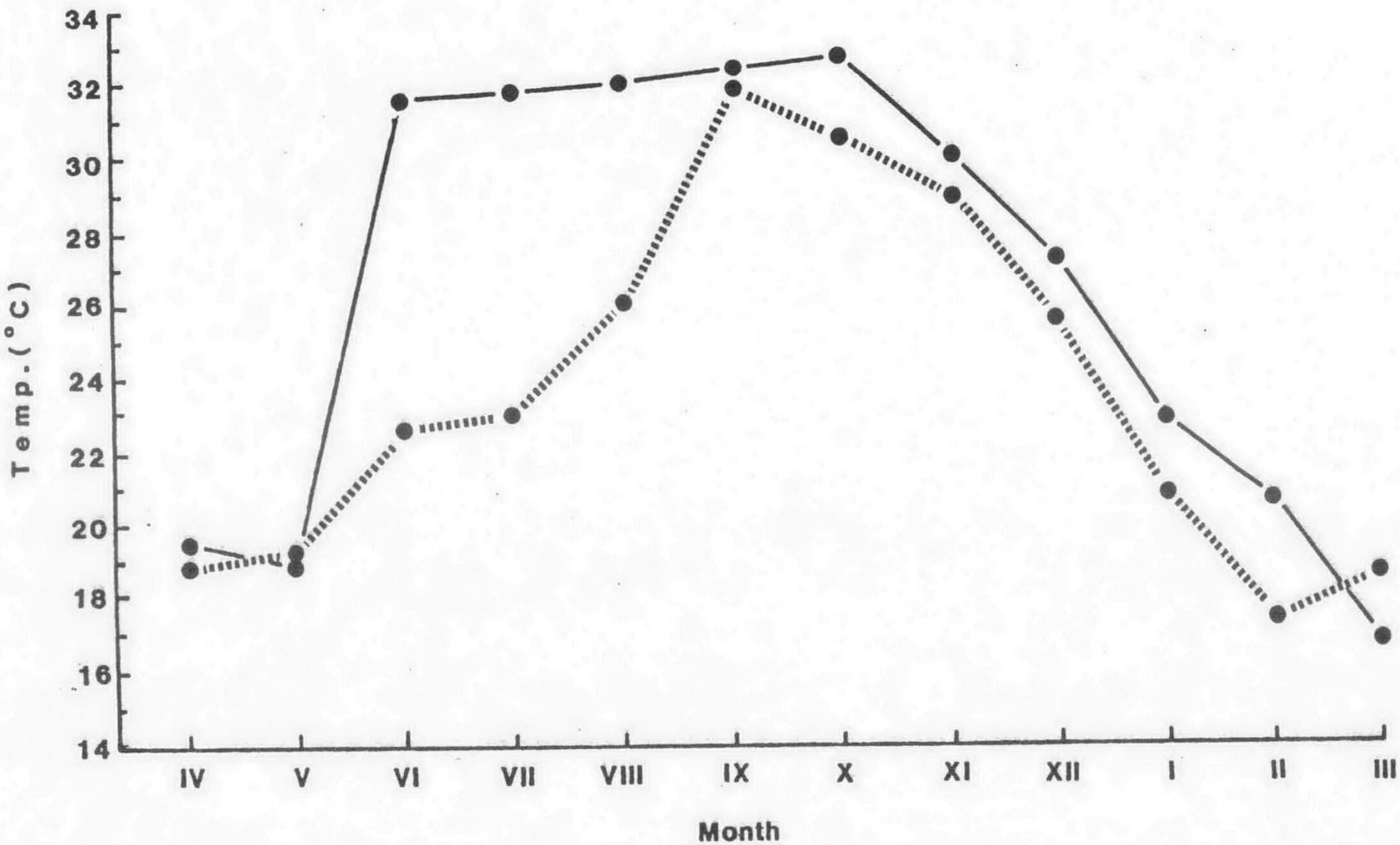

Fig. 3 - Mean wheat temperatures (local cv. 'Lakhish' o_______o, and imported cv. 'Hard Winter' o--------o) stored in different elevators during the period April 1980 to March 1981

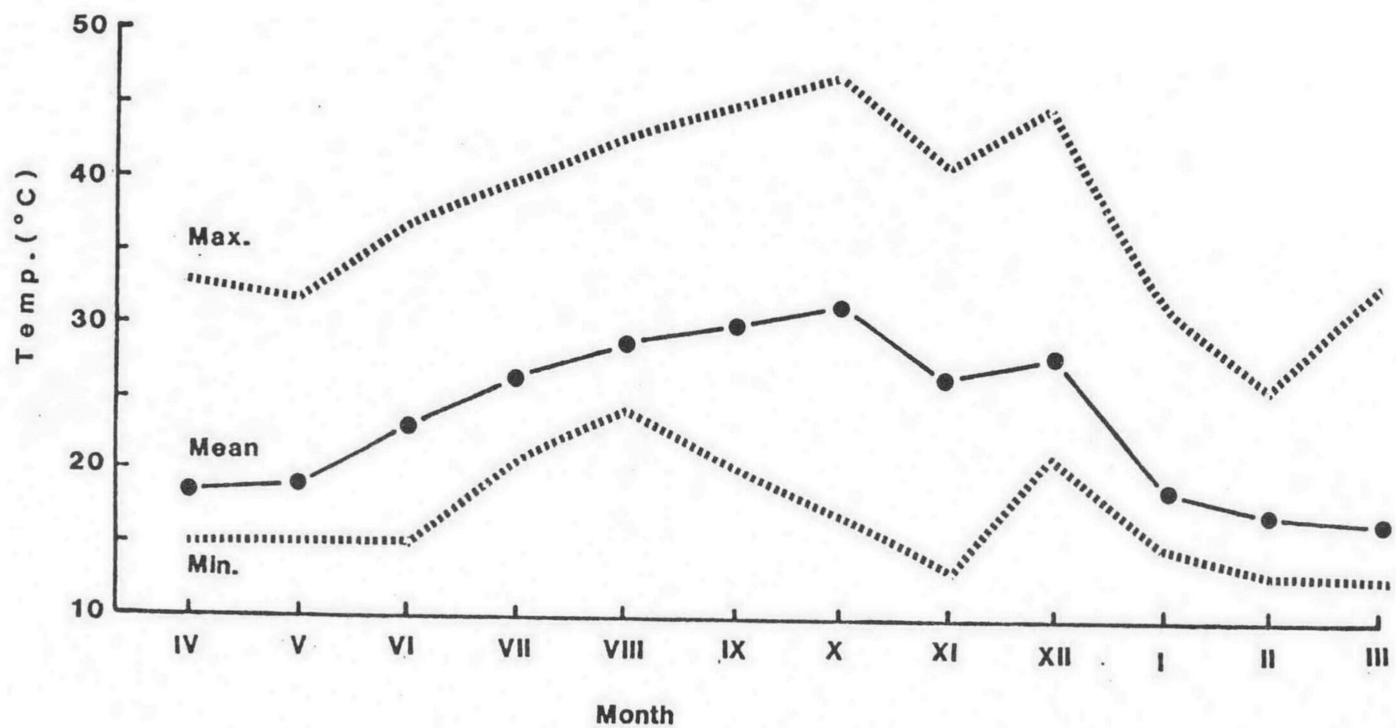

Fig. 4 - Mean, minimum and maximum temperatures (1011 samples) of soybeans stored in different elevators during the period April 1980 to March 1981.

2. Insect Infestation

The percent of infested samples as related to wheat temperatures is listed in Table 1.

Table 1. Percentage of wheat samples infested by specified insect species as related to bulk temperatures recorded at the sampling locations. The examined samples were taken during the period of April 1980 to March 1981.

Temperature Range (°C)	% Samples infested by specified species			
	Tribolium sp.	O. surinamensis	S. oryzae	R. dominica
11-15	22	32	11	2
16-20	10	22	6	1
21-25	17	25	7	1
26-30	40	57	16	4
31-35	29	54	17	7
36-40	57	62	11	14

The computer classified all lots of grain according to temperature within the ranges shown in the table. Thus, it can be seen that grain stored at the lower temperature ranges had a lower percentage of samples infested by the specified species. The percentage of samples infested by the two external feeders, Tribolium castaneum and Oryzaephilus surinamensis, was significantly higher than that by the internal feeders, Sitophilus oryzae and Rhyzopertha dominica. This distinct difference is directly related to the higher infestation level that is tolerated for the external feeders. The presence of one live adult internal feeder per sample (1 kg of wheat) calls for immediate response by the DSP - compared with an action level of three live adult external feeders per sample.

The large proportion of infested samples also requires explanation. Since aeration is the most intensively practiced method of grain preservation, insect reproduction and development are largely inhibited, but some survivals are to be expected.

Another example of the type of information that can be revealed is the level of infestation in relation to the sampling location in the bin (Table 2). Samples taken from flour mills show that the major infestations are located at the bottom of the bins. These figures, as well as those from elevators and central storages, show that the major infestation was recorded at the bottom. From this information it is concluded that emphasis on control should be focussed at the bottom of storage facilities, where the major infestations were recorded.

Table 2. Percentage of wheat samples infested by specified insect species as related to sampling locations in the inspected bins of flour mills and elevators. The examined samples were taken during the period of April 1980 to March 1981.

		% Samples infested by specified species			
		Tribolium sp.	O. surinamensis	S. oryzae	R. dominica
Flour Mills	1-3 m from surface	9.7	20.5	6.3	1.8
	Bottom	23.7	33.7	15.6	4.0
Elevators	1-3 m from surface	31.6	47.2	12.3	2.2
	Bottom	34.3	53.4	19.0	10.7

3. Use of insecticides

The system practiced in Israel is based on continuous inspection, which enables specific identification of problems and subsequent treatment, as contrasted to a regime involving the regular application of chemicals for insect control. The use of contact insecticides is restricted to surface applications and grain is not treated directly by admixture. The most intensively used method for conservation of the grain quality is aeration, with either ambient or refrigerated air (Navarro, 1976). For localized infestation, spot fumigations using methyl bromide or phosphine are applied (Bulbul *et al*., 1981).

The system involves minimum usage of insecticides, including fumigants, and is based on a tolerance level for insect presence which does not require widespread use of insecticides. However, the relatively large proportion of infested lots of grain has caused some concern among flour mill operators and research is underway on the introduction of controlled atmosphere fumigation as a substitute for conventional fumigation in this area.

Cost Camparison and Storage Losses

The above described system of monitoring grain quality in storage has a recorded loss of less than 0.5% in weight of the commodities stored annually (Navarro *et al*., 1977, 1979). The loss figure includes loss of weight due to the drying effect of aeration, which forms a significant part of this estimated loss.

On the basis of this information Table 3 was prepared to illustrate the inspection costs as compared with the value of the commodities inspected. The efficiency of the system is credited with keeping the losses below 0.5%. Without the information supplied by the inspection team, and without a professional approach for the possible solution of storage problems, it is estimated that storage losses in Israel would increase considerably. The inspection costs are 0.019% of the total value of the inspected commodities, which is a low price to pay when compared with the alternative of high losses without a system of monitoring grain quality.

Table 3. Cost comparison of inspection and annual storage losses in Israel.

		US $
Estimated value of inspected commodities		575,000,000
Estimated annual loss	<0.5%	
Estimated value of loss		2,875,000
Annual cost of inspection including salaries, travel expenses and equipment		110,000
Inspection cost as related to total value of inspected commodities	0.019%	

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