A bibliography intended to draw together what has been published or reported on grain storage losses/damage/estimation and detection. The main efforts toward increased food production have been directed toward greater agricultural production through better cultivation, high-yield varieties, and better fertilizers and insecticides. The necessity for good storage has not received sufficient recognition, partly because of a lack of understanding of the magnitude of losses occurring during harvesting and storage. Data on storage losses can be used as (1) a tool for directing future research and planning; (2) a basis for calculating justifiable expenditures on control; (3) a basis for estimating damage; (4) a means of evaluating the effectiveness of control measures; and (5) a basis for evaluating harvesting machines and machine components with respect to the damage they cause or produce. The bibliography is divided into four sections. The first included literature pertaining to internal infestation and detection procedures. The second concerns losses due to insects, rodents, and birds. The third concerns harvesting, handling, conditioning, and processing losses. The last section covers literature on nutrient, fungal, and germination losses. The four sections contain a total of 705 citations.
Losses Which Occur During Harvesting and Storage of Grains: A Bibliography
LOSSES WHICH OCCUR DURING HARVESTING
AND STORAGE OF GRAINS:

A BIBLIOGRAPHY

Prepared by

A. N. Mphuru
Faculty of Agriculture
University of Dar es Salaam
Morogoro, Tanzania

Prepared for the

AGENCY FOR INTERNATIONAL DEVELOPMENT
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Technical Assistance in Grain Storage, Processing and Marketing
and Agribusiness Development

at the
FOOD AND FEED GRAIN INSTITUTE
Kansas State University
Manhattan, Kansas 66506

Dr. William J. Hoover, Director
Dr. Leonard W. Schruben, Associate Director
PREFACE

Mr. A. N. Mphuru, Senior Lecturer in the Faculty of Agriculture, University of Dar es Salaam, Morogoro, Tanzania, spent four months at Kansas State University under a Fulbright-Hayes Fellowship, sponsored by the Council for International Exchange of Scholars. He was hosted at Kansas State University by the Food and Feed Grain Institute under contract AID/ta-C-1162, Technical Assistance in Grain Storage, Processing and Marketing and Agribusiness Development.

Prior to visiting Kansas State University, Mr. Mphuru had been active in grain storage work in Tanzania. He was principal investigator in a study to investigate the traditional grain storage methods in the rural Morogoro and Iringa Regions of Tanzania in which loss assessment was a major consideration. He also served as Director for the Second Course of the FAO/SIDA/Tanzania Sub-regional Training Center on Storage Pest Control held at the Faculty of Agriculture and Forestry of the University of Dar es Salaam, Morogoro, Tanzania May 26 - July 4, 1975.

During the time Mr. Mphuru was at Kansas State University he devoted most of his time to developing a bibliography on losses which occur during harvesting and storage of grains. He also took part in the 1976 AID Grain Storage and Marketing Short Course held at Kansas State University June 21 through August 6, 1976.

Over the past several years, considerable emphasis has been placed on increasing the production of the world's food supply to meet the needs of our growing population. Only recently has there been a realization, on a broad scale, that we need to increase our efforts in the area of harvest and post-harvest food loss reduction as a means of increasing the total available food supply.
Since the late 1940's, there have been various loss estimates published for various parts of the world. Some of these estimates are based merely on guesses, others on limited observations, and a few on well designed studies.

To put the harvest and post-harvest loss picture in proper perspective, there is a need to assess the information that is currently available. This Bibliography is an attempt to bring together in one publication a listing of the available literature on "Losses Which Occur During Harvesting and Storage of Grains." This effort should be of value to others pursuing the subject of food losses.

John R. Pedersen
Food and Feed Grain Institute
Kansas State University
Manhattan, Kansas
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**ATTENTION:**

It should be noted that the reports quoted under reference numbers 183, 248, 299, 300, 343 and 349 are restricted TPI documents.

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ACKNOWLEDGEMENT

The author acknowledges with gratitude the generous help of many persons and agencies who made this project possible.

The author is especially grateful to the Council for International Exchange of Scholars for financing this project and the University of Dar es Salaam for its willingness to release me for this period to carry out this project.

My sincere appreciation is expressed to Dr. J. R. Pedersen and Dr. R. Mills for their assistance, supervision, encouragement, transportation and other services while I was carrying out this project.

I am grateful to Prof. Knutson for the provision of office and office facilities. Last but not least I would like to express my sincere gratitude to Dr. W. J. Hoover and all others who made my stay fruitful and enjoyable.
INTRODUCTION

The main efforts towards increased food production have been directed towards greater agricultural production through efficient cultivation, using high yielding varieties, fertilizers, insecticides and good crop husbandry. The necessity for good storage of the harvest, won with such cost and difficulty, has not received sufficient recognition. The main problem has been due to lack of understanding of the magnitude of losses which occur during harvesting and storage. The nature and magnitude of these losses have been documented by several workers (Freeman, 1952; Herford, 1962; Howe, 1965; Parkin, 1956; Hall, 1970; Tygi and Girish, 1976; Jackson, 1976) and many others.

Most of these estimates have either been based on data from controlled experiments or from guesswork and as such have led to an over- or under-estimate of the extent of losses which occur under field conditions. Furthermore, most of these estimates give no information or clue on the progress of losses during storage.

There are several reasons why reliable qualitative and quantitative assessment of losses are important. Accurate assessment of losses is important and the data can be used: (i) as a tool for directing future research and agricultural planning, (ii) as a basis to calculate justifiable expenditure on control, (iii) in estimating damage that justifies control, (iv) in estimating the effectiveness of control measures and (v) as a basis for evaluating harvesting machines and machine components with respect to the damage they cause or produce.
Although many workers agree that there is a need for loss assessment there is no agreed method of storage loss assessment technique. Similarly, there is no agreed definition of grain "loss" or grain "damage". This is due to the fact that the storage losses are of a multiple nature, including losses in weight, quality, nutritive value, and market value. Each of these types of losses may have different significance that varies with people, time and place and in the face of existing methods, experts would proceed differently in estimating them (Harris, 1972). An agricultural engineer will be mostly interested in losses during combine harvesting, threshing, drying and handling. An entomologist would be mostly interested in losses due to insects while a nutritionist would be mostly interested in losses during processing.

Dobrovsky (1965) suggests that in order to overcome this problem, losses or damage should be expressed as an index. An index may be a ratio or another mathematical expression based on several factors and derived through a number of experimental observations whose relative values are assembled and placed in their logical positions in the body of the formulae. The computed damage index would preferably be a numerical expression which would indicate the current status of a given lot of grain. Since Dobrovsky suggested this procedure, very little work has been done along these lines. This bibliography is intended to draw together in one volume what has been published or reported on grain storage losses/damage/estimation and detection. The bibliography is arbitrarily divided into four sections. The first part includes literature pertaining to internal infestation and detection procedures. The second part includes losses due to insects, rodents,
and birds. The third section covers harvesting, handling, conditioning and processing losses and the last section covers literature on nutrient, fungal and germination losses.
DETECTION AND MICROANALYSIS


Describes the use of a low noise level audio amplifier, suitable microphone and a loudspeaker for detection of insect infestation in grains.


Describes a Simple Method of Detecting Internal Insect Infestation using the Principle of Nuclear Magnetic Resonance in which Magnetic Field Attracts Insects.


Describes an Instrument which uses the Ninhydrin Technique for Detecting Insect Infestation.

A non-destructive method of detecting insects in grains is described. Mechanical vibrations caused by the activity of the insects are amplified and the signal fed to an appropriate display system.


Methods are given which isolate, among other things mites, mite eggs, and mite feces; Part of the material floats, and part sinks in the Chloroform.

Describes the new radiographic paper that can produce image that can be viewed with reflected light. This has revolutionized the use of radiograph in insect detection; testing for seed viability; embryo development etc.


Chemical and physical tests for flour beetle eggs and excreta are discussed.

Describes a method of examination of foreign matter in flour which involves sifting, digestive with acid and staining with iodine.


Chemical and physical tests for flour beetle eggs and excreta are discussed.


Describes the use of sodium chloride solution with specific gravity of 1.20 to 1.26 for separating weevil-infested peas.


Describes a technique for observing and identification of mold in maize.


A method is described which uses an intermittent flow of a carrier gas with alternating intervals for sample collection and sample readout in conjunction with bolus-activated infrared CO₂ analyzer.


A method based on polarimetric determination of starch in calcium chloride solution and on the fact that damaged starch is digested more easily by α-amylase is described.


Cotton reviews various techniques available for detecting internal infestation.


A measured sample is boiled for 10-15 minutes in 10% NaOH. After cooling, water is added and the liquid is trained through gauze. Remains of larvae, cocoons, pupa etc. are then counted.


Describes a chemical indicator technique in which the body fluids of the insects produced a colour reaction with ninhydrin-inpregnated filter paper.

Describes a visual technique of examination utilizing glass mirrors for better vision.


Describes a technique which measures the temperature changes in infested grain.


Describes a technique which involves boiling with 10% NaOH; wash with 1.25% H₂SO₄; ignite; and weigh.

47. Farrell, E. P. and M. Milner (1952). Insect Fragment Problem in the Milling Industry. Contribution No. 219, Department of Flour and Feed Milling Industries, Kansas Agric. Exp. Station, Manhattan, KS.

Describes a technique of removal of insects from wheat by cracking, aspirator and entolier system.


A Method of separating infested grains by projecting each grain at uniform velocity into still air is described.


The radiographic process most appropriate to quarantine practice is presented.


Describes the use of Acid Fuchsin dye in staining egg-plugs.


Gives an account of the use of Giemsa stain (Azure II - Eosin) for staining the exoskeleton.


The use of Azure I or Azure A or Methylene Azure for staining insect fragments is described.

Results on the studies of the development of *Sitophilus oryzae* using Ashman-Simon infestation detector (Ninhydrin) is described.


A flotation technique using supersaturated solution of sodium chloride with specific gravity 1.198 followed by centrifugation and microscope observations is described.


Goosens describes the staining of egg plugs using gentian violet.


Describes the use of salt solution to float insect and rodent filth.


The fundamental procedure employs suction and manual shaking to evacuate all dust from corn and to trap it in distilled water. The dust is filtered into crucible, dried, and weighed to determine % dust.


He summarizes the procedures for detecting internal insect infestation using staining methods, (acid fuchsin, gentian violet, herberine sulfate), cracking flotation method and simple flotation method.


Damaged peas may be removed from a sample by flotation in a salt solution containing 300g of sodium chloride per litre of water.


A devise is described which effects a continuous separation of internally infested wheat from sound wheat. A stream of wheat is projected into still air by rapidly moving belts.


The use of ultraviolet and greenlights for attracting moths is described. The green light traps were satisfactory for this purpose.


This is a staining technique in which the kernels are first treated with urease solution (pH 6.8) for 5 minutes followed by addition of Neaslers reagent which forms a yellow to orange complex with rodent urine. Acuity of differentiation between normal and contaminated kernels is increased by examination with ultraviolet light.


This is a small trap that excludes grain kernels but permits the entry of grain beetles.


This is a compilation of filth separation and identification as used by Food and Drug Admin. Plant sanitation, rodent contamination, etc.


Describes the ultraviolet light to determine presence of rodent urine. The rodent urine fluorescent in ultraviolet light.


A very comprehensive review of various techniques of detecting insect infested kernels.


Describes the use of alkaloid berberine sulfate for staining egg-plugs.


A radiographic method for the detection of internal insect infestation in grain by means of low energy radiation from a cobalt-target beryllium-window x-ray tube is described.


Noted that the egg-plug count decreased as the grain was washed or subjected to abrasion.


Flour is treated with alcohol, centrifuged, treated with sodium chloride solution-glycerol solution, stirred and centrifuge eggs to surface.


Food treated with antiformin is centrifuged and the sediments are examined.


A new improved system for the determination of uric acid using the enzyme uricase is described.


ESTIMATE OF LOSSES DUE TO INSECTS

RODENTS AND BIRDS


Gives progress report on: data and literature collection on postharvest loss assessment; questionnaire survey to identify all people working on storage loss assessment; laboratory testing some methods to assess losses during storage.


Noted that losses in storage are of different types and hence the ultimate use of any estimate must be considered when conducting loss assessment. In arriving at the total loss, the pattern of consumption and grain disposal must be taken into account.


The author reviews the important factors involved when planning a project to estimate losses in stored grain at the village level. Both planning and technique methodology are discussed with reference to problems likely to be encountered.


Losses of the order of 20-30% are reported in the Congo basin.


Under laboratory conditions Callosobruchus maculatus caused a loss in weight of the order of 22.8%, 48.58% and 61.14% in grain, Phaseolus mungo, and wash respectively after a 4 week storage.


Noted that the normal losses to crop in India from diseases, pests, vermin, etc. may be placed at 10% of the total produce.

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Observed that wheat graded "weevily" had increased from 3.45% in 1948 to 4.28% in 1952. With light infestation (2%), the total loss was about 6¢ per bushel while with heavy infestation (10%) the loss increased to 45¢ per bushel.


In this popular article it is estimated that rats destroy 359 million dollars worth of stored crops and insects cause value decreases of 218 million dollars. The total post-harvest losses are put at 38 billion annually.


It is indicated that in the U.S.A. the losses due to insects amount to about 4 billion annually. It was estimated that there was two rats to every person on farms and one rat for every five city dwellers.


Attempt is made to assemble the information available on the various types of losses to agricultural crops and livestock for the year 1942-1951. Corn losses were estimated to be about 51,947,000 bushels, wheat losses 58,211,000 bushels and sorghum losses 24,223,000 bushels.


Work in Congo showed that after one year's storage the loss of weight resulting from insect attack was: for sorghum 50%; for beans 20%; and for groundnuts 15%.


It is estimated that the loss of the order of 20-30% occur annually during storage of grains.


Estimate of losses in USA and India are given. Discusses the shortcomings of the estimates so far reported. Noted that at farm level a farmer will constantly be withdrawing supplies for his own consumption and consideration should be taken into account when one is estimating losses.

Describes a simple method of estimating losses. The grain is separated into damaged and undamaged categories. The damaged sample is further subdivided according to cause and the loss in weight calculated according to a given formulae.


In Gambia by comparing the weight of insect-damaged and sound grains it was estimated that for the year 1968 the apparent loss in weight was 2,500 tons, while the cash losses were £180,000.


The survey to assess losses in rural areas showed that at harvest the damage is about 1% which rose to 7% damage in 5 months storage.


A comprehensive account on various projects going on on estimate of losses with particular reference to Africa. For each project an account is given on purpose, sampling procedure, methodology of assessing losses and results.


Back estimated that weevils destroy 1,260,000 bushels annually, 10% of Florida's crop. In South Carolina the losses were estimated to range from 2% to 75% with an average of 14%.


Small enclosed populations of the common rat (10 to 26 rats) each with access to one ton of sacked wheat for 12-28 weeks caused a loss in weight of 4.4% of the wheat. 70.4% of the wheat was fouled.


Discusses the biology, ecology and population dynamics of rats and their potential as pests of storage and field crops.
Records that in Germany in 1948 losses caused by insects was worth 10 mill. R.M. while in Kenya the level of damage could be as high as 50%.

Noted that field infestation was about 2%. In laboratory observations one bruchid can cause a 3-5% weight loss in a cowpea seed. The decrease in weight loss per individual insect is lower when there are several larvae per seed.


Estimate losses of 5-50% from the time reaches maturity to the time of their consumption. He categorizes the type of losses into: Field losses, harvesting losses, shelling losses, handling losses, drying losses and storage losses.

The possible use of radiation to control pests is described. The radiated species caused less damage than normal insects. After 5 weeks storage the loss in weight was 3-11% as compared with control.

Reviews the type and extent of damage caused by rodents. Noted that there are few accurate estimate of losses. May estimates are guess work; few from experimental work.


Gives results of estimate of losses of cowpeas from monthly samples from the market. Noted that there was a correlation between the number of bruchids per seed and extent of damage. By extrapolation using this technique he found out that about 24,000 tons are being lost annually which are worth $840,000.


Gives estimates due to various storage pests, 20 to 30%.


Discusses in detail the value of reliable crop loss data.


Reviews the value and need for crop loss information.


Data is given on effect of different sowing dates on field infestation by cowpea weevil. The weight loss caused by the weevil was closely correlated with the level of infestation.


Cleare has published some interesting data concerning the weight losses caused by pests to stored rice and has attempted to translate these losses into monetary losses.


From insecticide trials the loss in gross weight of beans over a 5 month storage was 11%; for maize 4.9%; and for sorghum 2.1%.


He estimates that on a world basis the losses due to insects, fungi and rodents is of the order of 10%. He lists the results from the FAO survey which cover 27 countries. The total loss in estimated about 25,750,000 metric tons, without considering farm losses. Taking farm losses into account the total loss would be about 65,000,000 tons which is enough to supply caloric value for more than 360,000,000 people.


Estimates that wheat in the Great Plains of USA may suffer a loss of 10% in one season and corn in the deep south may be destroyed at the rate of 9% per month while in storage.


It is estimated that the rat population equals the human population and in some communities may be twice as great. Their young are produced at the rate of 3½ million everyday. It is estimated that they destroy as much food as 200,000 American farmers can produce.


By comparison of treated and untreated grain in the farm cribs in Kenya it was observed that with sorghum the loss in weight after 9 months storage was 18% and about 36% after 12 months storage.


Estimates that India loses 1 million tons of grain annually due to pests.


On a worldwide basis, Cramer estimates that losses to pests is about 35%. These losses include destruction by insects, weeds, and pathogens.


Darling observed that the percent damage after a 9 months of storage was 84% and the loss of weight was 14% for maize. The extent of damage rose to 98.4% and loss of weight to 27% after 15 months storage.


Working with beans in Uganda, Davies observed a positive correlation between the extent of damage and loss in weight. A 50% damage gave a weight loss of 6.4%. From experimental work loss in weight after 6 months storage was 5%.


The author outlines the main types of direct and indirect damage together with the terminology in general use. He distinguishes quantitative, qualitative and socio-economic type of losses.

He points out the serious disadvantages of estimating the loss of stored grains by mere reference to the % damaged and discusses the various factors that ought to be taken in arriving at a true estimate.

The author reviews the subject of losses in stored products and states that it is not easy to convert in a meaningful figures the economic, hygienic and nutritional losses. He classifies losses into direct and indirect losses and subdivide them into smaller categories.


He classifies damage into 3 categories notably direct damage; indirect damage and economic damage.

Noted that there was little difference in extent of damage between undecorticated and decorticated nuts, but there were large differences in the build up of free fatty acids.

Rodents not only consume food but contaminate it. Rats eat about 20g food daily; void about 20 droppings daily; and 16 ml. of urine per day. Each rat deposits enough droppings daily to render one bushel of grain unfit for milling.


In Alabama corn stored in shuck after a period of storage of 9 months showed a mean value of damaged kernels of 37.7% while the shelled corn showed a mean damage of 86%.

During the year 1962 loss from insect damage to farm stored crop in Alabama, Georgia and Mississippi was about $10 million. After one year storage at harvest the loss was already $4 million.


A summary of the research conducted in Georgia, Alabama and Mississippi is given. Using x-ray detection technique he noted that damage to ear corn increased from initial of 11.6% to 37.5% after a year of storage. He estimates a total loss of about $9,875,332 for the year 1964 in the three states.


In Finland it has been estimated that grain pests cause a loss of about 2% in imported bread corn.


The average damage was approximately 10% at harvest time. This gradually increased to 17% in May. Attempts to separate damage according to pest involved showed that Sitophilus was the most destructive.


In the control treatment it was noted that the percentage ears infested increased to 100% in 10 months storage while the percentage kernel damage increased to 72%.


The average number of kernels of grain damaged by one larva during its development for seven different species of insects is reported.


Freeman classifies damage into various categories including: reduction in weight, heating, reduction of food value, loss in germination, tainting of food, contamination etc.


Attempt is made to correlate the number of insects per bean and the percent loss of weight. The average weight loss caused by one bean weevil in 60 days was 3.5%.


From the result of survey work it is estimated that about 4% of the total sorghum and millet crop is lost to stored product insects every year.


From the results of long term storage trial it was observed that damage increased from 0% to 89.3% after 21.5 months in store while the % weight loss increased from 0 to 24.3%.


Girish et al. gives a very comprehensive review of the type and extent of losses and damage caused by rodents.


A survey on storage losses in India 1973/74 showed that the % losses in weight after 6 months storage range from 0.06 to 9.7%. A formulae used in calculating losses is given.


The author gives information about the most important pests, their magnitude of their damage and their distribution in Peru. He estimates that about 10% is lost during storage.


Attempt was made with very small numbers of defective beans to estimate quantitative losses.


The author points out that losses due to insects is about 5.6%; that due to rats 6-10% and due to moulds 1.2%.


Hall reviews storage losses in various tropical countries.


Groundnuts is the major cash crop in Gambia accounting for about 97% of the export crop. Average loss was estimated about 3% equivalent to £90,000. The reduction in available oil accounted for a loss of £175,000.


A comprehensive review of storage losses and methods of assessment.


Attention is drawn to the scale on which foodstuffs may be damaged by insects. Figures are cited to show the worldwide nature of the problem. Problems attendant upon assessment of storage losses are discussed.


A very comprehensive review covering various aspects on storage losses.


An investigation into the weight of grain eaten by a small population of sitophilus at three different temperatures is described. Assessment of damage caused was made by weighing and radiography. The average of grain consumed by each larvae was about 28.7mg. and the mean weight of each adult was 2.7 mg.


Huysman reports some of the results on estimating losses which have been made by a committee on losses of food grains during post harvest handling. According to the committee more than 50% of the total loss was due to rodents. For the whole India an average loss of nearly 2 million tons of grain per year for the period of 1962-1965 is reported.

278. Ibrahim, M. M. (1972). Damage and control of the field or the nile rat, *Arvicanthis niloticus*.


Investigations showed that weevils caused 74.7% loss in weight in single kernels and 12.9 and 25.9% in 20 and 250 g samples respectively. Chemical analysis showed an increase in protein content with increasing infestation.


He reports that losses caused by grain storage pests totals 5% of the crop in U.S.A. In West Germany, the granary weevil alone caused a 2% loss which is equivalent to 120,000,000 marks. In Mexico he reports losses of the order of 15% which is equivalent to 5 million tons.


In the appendix he lists extent of losses which have been reported by various workers.


Loss in weight during storage due to insect feeding under different geophysical and rainfall conditions ranged from 4.3% at maximum and 1.5% minimum. Loss in weight was directly related to storage method, design and local climatic conditions.


Losses of the order of 8.6% were experienced after the storage period.


The rat populations was higher in the vallages than in the towns. Losses of food grains due to rodents are estimated to range from 1.36 to 3.59 tons per year. A comprehensive account of populations, ecology and damage is given.


Describes a methodology of estimating losses by comparison of damaged and undamaged grains.


A critical review on grain storage losses and allied problems.


Reviews some estimate losses which have been reported in India. These reports mention a 30% loss of the total subsistence agricultural production during handling and storage. Cereal and pulse losses were put at 20%. Paddy losses during storage showed an average loss of 11%.


Pimental et al. reports that post-harvest losses may be about 20%, ranging from about 9% in U.S.A. to 40% in some developing countries. When post-harvest losses are added to preharvest losses, total food losses due to pests are estimated about 48%.


Storage losses due to Khapra beetle was estimated to vary from 2.25 to 5.47%.


Storage losses for Ghana are put at 15% for maize, 20% for beans, 15% for yams, and 5% for cassava.


Richards et al. found out that one larvae of Ephesia consumed about 47 embryos of wheat.
It was observed that one rice weevil larva turns about 15 mg of grain into carbon dioxide and water and produces 14 mg of feces while developing into a weevil weighing 2.4 mg. About 2/3 of the endosperm of a wheat kernel is consumed by a weevil.


Schulten estimated that in 1971 about 1% of the maize harvest was lost during storage. He indicates that from the survey results the losses of maize can be estimated accurately provided the following data is known: total production and how it is made up by the different varieties, the pattern of disposal, etc.


Noted that 3% insect damage in 1,000 bushels of wheat would cost a farmer $15 in wheat destroyed. A chart is presented which translates insect damage to dollar loss per 1,000 bushels.


Sinha proposes a new technique of assessing losses due to insects by calculating energy budgets of several major stored product insects. By measuring the exact amount of food consumed by each insect it is possible to tell the exact and potential caloric loss of food. Using this technique they found out that 58.2% of the caloric content of wheat kernel was consumed per Sitophilus during its development from egg to adult.

The average amount of grain damage by weight, by number and amount of grain per larvae during development varied in different varieties. The average loss of weight varied from 1.5% to 3.7% while the % damage varied from 13.2 to 22.7.


*Sitophilus granarius* bores mainly into the dorsal surface of the moist grain but around the germ end of the dry grain. *Rhizopertha dominica* spread dorso-ventrally in the damp grain but also prefers the germ end when the grain is dry.


Describes various indices for measuring damage of wheat. These include decrease in viability, development of fat acidity; test weight, baking tests etc.


A very comprehensive review in a tabulated form under the following headings: place, kind of storage, commodity, loss in weight, major pest, period of storage, country, investigator and remarks.


Reports damage losses, weight losses and germination losses of various crops in Botswana. Maximum weight losses encountered were 46% for sorghum, 55% for maize, 6% for millets and 23% for beans.


Changes and losses which occur during storage are described. The results after 5 months storage indicate that the weight loss increased from 0.9 to 3.15%; the weight volume ratio decreased from 0.85 to 0.59; the insect population increased from 0 to 7,650 per 500 g. sample and the viability decreased from 85% to 5%.


Reports on the population dynamics of rodents and their potential as pests of stored products.


This paper describes the results of the work aimed in determining the cost of preventing insect damage to wheat in commercial stores in U.S.A. Control costs varied roughly with the number of bushels stored. Individual operations ranged from 0 to 2.25 cents per bushel, averaging 0.45 cents per bushel.


Weight losses caused by *Sitophilus oryzae* during the developmental period in wheat is described. The mean loss in weight per infested wheat kernel was found to be 0.67% after the first week of larval development; 2.36% after the second week; 6.52% after the third week, 13.59% after the forth week and 20% upon the completion of emergence.


He outlines the nature and type of losses caused by pests. Estimates that on a world-wide basis the losses due to pests range between 5-10%. This equals to the quantity of food required to feed 130 million people for one year.


Worthington estimates that in Uganda under the present storage arrangements, about ½ of the food crop is lost annually through ravages of insect pests and rodents.
HARVESTING, HANDLING, CONDITIONING AND PROCESSING LOSSES


356. Agnes, J. B. (1968). How do you measure grain damage? Symposium on the grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

One of the reasons for measuring kernel damage is to evaluate harvest machines and machine components with respect to the damage they cause or produce. Methods described for measuring damage include: 1. counting damaged vs sound (visual). 2. Sieving. 3. Comparing the $H_2O$ absorption characteristics of 100 sound of 10% damaged corn.


The results of the survey suggested that the levels of grain damage occurring in combine harvesters under commercial conditions are similar to experimental ones. The damage was closely related to the speed of the drum and moisture content. The mean % of broken grains was 3.9%.


Arny and Sun in Minnesota found the greatest % of dry matter in wheat and in oats 1 day before maturity. Losses increase following delay harvesting.

-41-

366. Bailey, J. (1968). Problems in marketing damaged grain and corn. Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

Bailey indicated that damage to corn reduced the value to the producer by 3 cents a bushel for every bushel of corn grown and that a large % of corn was sold as No. 3 because of the amount of foreign material.


This is a popular article defining "sick wheat" as dead wheat and emphasizing the importance of reducing the moisture of wheat to 14% or less before storage.


Burnett et al found in studying the effect of delayed harvesting upon the yield of wheat that the duration of the harvest period depended on three factors - soil, climate and variety. Losses increased with delayed harvesting.


391. Ceska, V. (1971). Effect of mechanical damage to the biological 
activity of winter wheat (Cze) Zamed Tech. 17(7):457-463. (Eng. 
Summ).


from pneumatic conveying. ARS-NC-5 USDA.

Stillwater, Oklahoma.

high velocity impact on the germination and damage of cotton-seed. 


397. Chymachenko, I. (1968). Method for determination of grain breakage and 
grain losses in combine harvester tests (Russ.). Mekhaniz. Elekrif 

398. Cooper, G. F. (1968). Corn damage as influenced by some variations of 
Agric. Eng. Dept.

399. Davies, A. C. W. (1964). The relative susceptibility to threshing 
10(1):122-128.

400. Dios, C. A. de (1973). Kernel damage in mechanical maize harvesting 

401. Dodds, M. E. (1966). Grain losses in the field when windrowing and 

losses by the C-2 harvester/thresher (Rum.). Mec. Electrif Agrig. 
18(6):12-17.

403. Doll, H. (1975). Reduction and avoidance of loading and transportation 
losses during cereal recovery. (Ger.). Dtsch. Agrartech. 25(6): 
270-272.

induced by mechanical abuse. Diss. Abstr. Michigan State University, 
East Lansing, MI.


416. Foster, G. H. (1968). Grain damage from high-speed drying. Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

High-speed and high-temperature drying may damage grain by increasing brittleness of the grain; stress cracks or endosperm fissures.


419. Foster, G. H. and L. E. Holman (1973). Grain breakage caused by commercial handling methods. U.S. Dept. Agric. Marketing Res. Rep. No. 968. Reports investigations designed to determine the extent and cause of physical damage to grain by equipment used in handling grain. Drop weight was the most significant test variable in the free-fall and spouting tests. In the grain-thrower tests, the belt speed was the most significant.

420. Forth, M. W. (1968). The challenge of measuring kernel damage. Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.


426. Garg, O. P. and N. S. Agrawal (1966). Quantitative and qualitative losses in the production of rice. Bull. Grain Techn. 4(1):24-27. It has been estimated that from 1 to 2% paddy is lost in harvesting and threshing process. In terms of quantity this is about 0.5 mill. tons. In storage the losses are about 5% of total production. During processing about 10% is lost.


Gives a bibliography in chapter seven on grain damage and grain losses during harvesting, handling and threshing.


Discusses types of damage of soybeans. Noted that insect damage is not serious but kernel damage is serious as it affects the oil content of the soya. Most of the loss in soya is mainly during combine harvesting.


This was an attempt to determine the characteristics of breakage that result from the shelling process. The data included particle size as related to various factors such as moisture content.


Starch grains may be damaged during milling. Damaged starch granules microscopically look flat with faintly outlined appearance. They stain pink in aqueous congo red whereas normal granules are unstained.


462. Kaminski, T. L. (1968). Need for standards for evaluation of grain damage. Symposium on grain damage - held under the auspices of the ASAE, Iowa State University, April 1968.


Kernel velocity, moisture content, impact surface, angle of impact, size and shape of grain - all significantly influenced impact damage to corn kernels. As the moisture content of the kernel decrease from 22.2 to 12.3% the damage increases. Most broken kernels were split longitudinally.


Kisselback 1925 in Nebraska found that wheat had its maximum amount of dry matter 2 days before it was mature. Delayed harvesting caused losses.


Extensive sampling has shown that an almost linear relationship exists between the initial M.C. and dry matter losses when stored grain is cooled but that losses are lower with continuous than with intermittent ventilation.

481. Kreyger, J. (1972). Drying and storing grains, seeds and pulses in temperate climates. IBVL, P.O. Box 18, Wageningen, Holland.


Wheat infested at a level of 41 internal forms per 100 g of dirty wheat lost 1.1% of its weight due to insect feeding during storage period of 11 months. The entoleter-scourer aspirator used in cleaning of infested wheat prior to milling reduced the number of insect infested kernels by 40%. Milling a straight grade flour of 0.48% ash from wheat infested with 41 internal forms per 100 g of dirty wheat results in 4.5 lbs less flour per 100 lbs of wheat than was obtained from comparable noninfested wheat.


Lundstrom, T. (1967). Losses in tests and in practice (Swedish). Traktor Jour. 6:448


Maywald, F. (1968). Do grain grading systems meet grain marketing needs? Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.


Starch granules may be damaged mechanically during milling.


524. Perry, J. S. and C. W. Hall (1965). Mechanical properties of pea beans under impact loading. ASAE Trans. 8:191-


Mechanical damage during harvesting depends primarily upon moisture content and cylinder speed; optimum moisture content of beans should be 17–20% and that of the pods 12% or below.


532. Proceedings of the grain damage symposium. Ohio State University, Columbus, Ohio, 1972.


The screw conveyor causes only a very small amount of damage to dry shelled corn when operated at full capacity. If the conveyor was not at full capacity slight losses/damage occurred. Corn dried at high \( T^0 \) increased level of damage.

541. Saul, R. A. and J. L. Steele (1968). Relation of mechanical damage to drying and storage time. Symposium on grain damage held under the auspices of the ASAE, Iowa State University, April 1968.


It was observed that the yield per acre and the protein content in the grain increased steadily as the grains dry from 50% moisture to 25% moisture in the field before harvest. Delay in harvesting caused losses.


The results of experiment showed considerable variation. Main sources of variation being men-differences and sampling differences. The precision can be improved by (1) increasing sample size (2) increasing sample numbers (3) increasing number of determinations on sample.


Smith studying mechanical corn picker studies found that when the kernel moisture dropped below 15%, the loss of shelled corn increased rapidly. Losses by both ear droppage and shelled corn increased as harvest was delayed beyond full maturity.


568. Uhrig, J. W. (1968). Economic losses of damaged grain. Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

Uhrig describes damaged grain as one consisting of scabby, frosted, sprouted, moldy and heat-damaged kernels - including all damage to grain quality.

From the economic point of view losses tend to be based on money.


Describes the physical properties of the cob and kernels that affect kernel damage. These factors include moisture, kernel strength, cob moisture, kernel age, cob strength, kernel diameter, ear length, ear diameter, etc. Multiple regression analysis revealed that kernel detachment force, kernel and cob strength, kernel thickness and M.C. are major factors affecting kernel damage.


584. Winter, J. W. and G. H. Foster, (1969). Mechanical damage to grain during handling in commercial facilities. Symposium of grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

The project was intended to find the levels of damage during:
(i) Elevating and discharging
(ii) Filling bins
(iii) Sprouting into a rail car or ship
(iv) Trimming a car or ship

Free drop was the most severe treatment tested and caused the worst breakage.

586. Young, E. and W. F. Buchele (1968). Threshing damage to soybeans. Symposium on grain damage held under the auspices of the ASAE. Iowa State University, April, 1968.

Gives a detailed account of the factors affecting bean damage in soya. Noted that damage beans have lower % germination and are highly susceptible to fungal attack.

Noted that the major factors affecting damage were M.C., pod moisture.
NUTRIENT LOSSES, FUNGAL DAMAGE
AND LOSSES IN GERMINATION


Heating of grain was attributed to biological oxidation of dextrose and similar sugars, mainly in the embryo. Respiration increased to maximum at 55°C. but enzymes were largely inactivated at 65°C.


The fatty acids in the oil is related to the degree and type of damage present in the grain. From the work above it was found that there was no marked difference among the free acids, released by damage grains.


A rapid and simple method for determining fat acidity in grain utilizing a grinder-extractor to shorten the extraction time is described. This method gave slightly lower values. The maximum fat acidity values accepted for little or no deterioration are 10 for beans, 22 for soybeans, 20-25 for cereals.


Reviews critically various types of changes of rice during storage. These changes include changes in color, odor, eating quality, physiochemical changes, changes in carbohydrates and nitrogenous compounds, lipids, enzymes and vitamins. This publication is a must for anybody interested in this topic.


Bottomley et. al has demonstrated that there is a marked disappearance of non-reducing sugars in corn stored under conditions favoring deterioration i.e. high R. H. etc. under high T° and R.H. the total water soluble nitrogen and reducing sugars increased. Viability decreased. Changes in non-reducing sugars were considered the best index of deterioration.


Both aerated and sealed corn was stored at humidities of 80-100%. An increase in free fatty acids, a decrease in non-reducing sugars, and a drop in viability were found to be associated with high moisture content.

Grains treated with mercurial fungicides at the rate of 2 oz. per bushel were not injured when stored for 12 months; but at the end of 24 months the speed of germination was reduced. With a treatment of 3 oz. per bushel, a greater reduction occurred.


When stored in metal cans soybeans dropped only 2% in germination the first year. Over an 8-year period the germination percentages were 58, 46, 33, 17, 8, 5 and 1.


Under laboratory storage conditions, at Norwood, England, the small grains tested deteriorated slowly over a 5- to 9-year period, followed by a rapid drop. Longevities were: wheat and barley, 10 yrs; oats, 14 to 16 years; legumes, 10 to 15 years.


The oil contents of samples of compound feeding stuff when determined by simple solvent extraction appear to decrease progressively as the age of the sample increases. These losses can be substantial, even over short periods.


Loss of viability was attributed to the precipitation of proteins. Formulae was given for the prediction of longevity.
A review covering most phases of seed physiology including anatomy, chemical composition, water relations, respiration, germination, dormancy storage and metabolism.

A review of a number of reports in regard to seed deterioration. Particular attention is given to seed storage and deterioration. Precipitation of proteins is advanced as a likely cause of loss of viability.

A review of work related to seed longevity up to 1938, concluded that the most plausible cause of seed deterioration with age is the degeneration of the nucleus, preventing normal mitotic division.


Observed changes in the concentrations of certain individual free amino acids during storage at 19.5% moisture.


Polarimetric starch analyses in which starch is extracted from the corn kernel with 90% dimethyl sulfoxide (DMSO) at room 0°C is described.


Studies to determine losses in food stored in underground pits revealed decrease in % germination; increase in free fatty acid and increase in damaged beans.


Life expectancy of Turkey Wheat was determined by a formulae based on the rate of coagulation of proteins at different temperatures and temperature durations. Predicted life of wheat with 9% moisture stored at 0°C. was 938 years and with 12% moisture 393 years.


Using flinty maize it was found that 70% of the total protein was found in the endosperm in which conc. gradient exists from the outer to the inner layers.


During storage there was an increase in reducing sugars and fat acidity and a decrease in non-reducing sugars. Loss in germination was associated with increases of reducing sugars and fat acidity.


Effect of insect damage on germination is described. It was observed that heavily infested samples reached a maximum of 78% germination while sound kernel reached as high as 90%.


Howe provides excellent review on loss of viability of seeds in storage attributable to infestations of insects and mites.


Mold-free grain respired at a uniform rate whereas the inoculated seeds showed a rapid rise. Germination of seed stored 19 days was injured by moisture content at 14.9%, as was also mold-contaminated wheat with M. C. at 14.9%.

Rice was stored 22 wk. with moisture at 3.9, 6.6, 9.5, 11.8, and 14.1% at T°s of 0° to 20°, 25°, and 35° C. Free fatty acids increased as both moisture content and T° increased.


Bibliography covering all aspects of seed technology including morphology, physiology, chemistry, germination, seed treatment, seed testing, etc.


A bibliography covering all aspects of seed technology.


Describes the standard method used for seed testing.


Gives an annotated bibliography on seed deterioration - with about 500 citations. The bibliography covers different types of seeds including forest tree seeds.


Jones and Gersdorff observed that prolonged storage of wheat and milled wheat products decreases protein nitrogen and increases free amino acid nitrogen.


The results show that there is a decrease in the solubility of the proteins (2) A partial breakdown of the proteins - indicated by a decrease in true protein content (3) a decrease in digestibility. The extent of the alterations were influenced by T°, type of container, duration of storage; changes in ground corn were greater than sound corn. Significant decreases in feeding were also found.

Estimates that about 1% of the world's supply of grain and oilseed is lost due to fungi attack.


He noted that average weight of seeds damaged by different number of bruchids developing within each seed is reduced by about 2.4, 4.5, 6.2, and 7.1 gm. respectively; the loss in wt. being about 12.0, 22.5, 32.0 and 35.5% respectively - the amount of food taken by each grub during its developmental period gets gradually reduced depending in the number of grubs developing in each seed.

659. Karper, R. E. (1928). Longevity and viability of Kafir seed. J. Amer. Soc. Agron. 20:527. Kafir seed stored under atmospheric conditions at College Station, Texas, lost only 12% viability in 7 years and 23% in 10 years.

660. Karper, R. E. and D. L. Jones (1936). Longevity and viability of sorghum seed. J. Amer. Soc. Agron. 28:330-331. Sorghum seed stored under prevailing conditions at Lubbock, Texas; dropped gradually in germination over a 9 year period, then in the following 10 years dropped rapidly to 0.5%.

661. Kik, M. C. (1943). Thiamine in products of commercial rice milling. Cereal Chem. 20:103-109. Losses of thiamine due to the process of parboiling of rice may be as high as 45%.


Rice with a moisture content of no more than 12% maintained germination when stored at normal granary temperatures.


Hulled rice stored in straw bags lost its flavor and viability rapidly.

Losses in thiamine may be as high as 75% when stored in bag depending on physical conditions prevailing during the storage of rice.


8 varieties of millet, including spp. of sorghum Pennisetum, Eleusine, Setaria, etc. were dried and stored in sealed bottles. Germination of 70% was maintained for 26 months for sorghum spp. When seed was stored in gunny sacks germination dropped to 4 to 38% in 1½ years.


A rating scale is proposed for experimental use for expressing the degree of deterioration in samples of shelled maize. The scale ratings are assigned to appropriate combinations of % germination and amount of infection by spp. Aspergillus and Penicillium.


Provides excellent review on the effect of fumigants on the viability of seed.


Paper Electrophoresis of free amino acids provided a rapid simple and convenient method to detect changes in the free amino acids of wheat during storage. Using 0.025M potassium-hydrogen-phthalate solution (pH 4.0) as a buffer a good resolution of amino acids was obtained. Electrophoresis of good quality wheat was characterized by a high glutamic acid peak. Glutamic acid peak decreases with deterioration.


Changes in sugar content and viability are described.


Mookherjee found out that the question of damage as a result of continuous breeding of the pest in various grains was as follows: Rice suffered mostly with 100% damage after 4 months. The damage was restricted to nibling in the germ points and no other portion of the grain were eaten up. Feeding on other seeds was not restricted to the germ but extended to other parts.


A well documented bulletin of 10 chapters covering longevity of seed, hygroscopicity, drying, change in composition during storage, dormancy, and treatment in relation to storage.

Provides excellent review of the hazards of fumigation to the viability of seed.


Wheat stored at low $T_0$ (4.5 $\pm$ 0.5°C.) and low $O_2$ levels is contrasted with wheat stored at ambient conditions. The viability of wheat stored at low $T_0$ remained high 96% while that stored at ambient $T_0$ fell to 39%. Free fatty acid values increased with time but the rate was higher in wheat stored under ambient conditions.


The following changes/deterioration occurs during storage:
(1) Oxidation of unsaturated fatty acids
(2) Decrease in lipids due to oxidation
(3) Decrease in nonpolar lipids
(4) Rapid disappearance of glycolipids and phosolipids.


Shelled dent corn from the seed of a simple cross of high carotene percentage stored for 3 yrs. was found to lose the carotenoids content at rate which approximately logarithmic function of time. Losses being more rapid at an early part of storage.


   This article discusses the effect of various types of processing and preservation upon the vitamins and trace element content of foods. Vitamin B1, Pantothenic acid and trace elements were studied in particular. "Refining of grains caused considerable depletion in relation to nutrient content.


   Tanfel et al. investigated the changed in the di- and trisaccharide contents of wheat during storage under good and poor conditions. Under good conditions the conc. of various sugars remained unchanged but when wheat was stored at high moisture and T°, sucrose glycodi-fructose and raffinose contents decreased while maltose content increased substantially.


