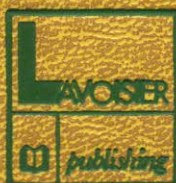


**PRESERVATION
AND STORAGE OF
GRAINS, SEEDS
AND THEIR BY-PRODUCTS**

**CEREALS
OILSEEDS
PULSES AND
ANIMAL FEED**

Edited by J.L. Multon



Contents

<i>List of Authors</i>	V
<i>Preface</i>	XXI
<i>Preface to the French edition</i>	XXII
<i>Foreword</i>	XXIII
<i>Note</i>	XXIV
INTRODUCTION : Spoilage mechanisms of grains and seeds in the post-harvest ecosystem, the resulting losses and strategies for the defense of stocks, by J.L. Multon	
	3
1. The post-harvest ecosystem and the biophysicochemical properties that characterize it	
	5
1.1 Grains after harvesting : a system of living organisms in unstable biological equilibrium - 1.2 Physical grain properties affecting storage phenomena - 1.3 Technological and nutritional qualities to be preserved	
2. Physicochemical spoilage mechanisms	
	18
2.1 Causes of spoilage - 2.2 Environmental factors - 2.3 Interactions between environmental factors and the causes of spoilage - 2.4 Technological consequences of spoilage	
3. Strategy for the reduction of post-harvest losses	
	33
3.1 Definition of the "sanitary condition" of grains - 3.2 Spoilage criteria - 3.3 Estimation of probable storage life - 3.4 Storability assessment of a recently collected batch and quality evaluation policy	
4. Technical measures applicable to grain and seed storage	
	46
4.1 Storage of grains in an oxygenated atmosphere (aerated non-airtight silo) - 4.2 Grain storage in airtight silos	
Conclusions	
	52
Appendices	
	59
1 HISTORICAL EVOLUTION OF STORAGE TECHNIQUES AND POLICIES, by F. Sigaut . .	
	65
1. Introduction	
	65
2. Techniques	
	66
2.1 Stored products - 2.2 Preparation of products for storage - 2.3 Conservation of products during their storage - 2.4 Preservation of stored products	
3. Storage, production and society	
	76
3.1 Storage and technical system - 3.2 Storage and physical environment : pests, cultivated plants - 3.3 Storage and physical environment : climate, chance - 3.4 Storage and society : scarcities and "surplus granaries" - 3.5 Storage and society : history and prehistory	
Conclusions	
	83

PART I - PHYSICAL PROPERTIES OF GRAINS	87
2 INTERACTIONS BETWEEN WATER AND THE CONSTITUENTS OF GRAINS, SEEDS AND BY-PRODUCTS, by J.L. Multon	89
1. Water content and water activity	90
1.1 Water content (H_2O %), quantitative factor - 1.2 The thermodynamic concept of Water Activity - 1.3 Correlation between a_w and water content: the isothermal sorption-desorption curve	
2. Nature of the interactions responsible for the affinity between water and foods	93
2.1 The water molecule - 2.2 Interactions on the molecular scale - 2.3 On the macromolecular scale - 2.4 Lipids	
3. Characteristics and properties of sorption-desorption isotherm curves .	106
3.1 Macromolecules (amorphous or partly ordered structures) - 3.2 Small crystalline molecules - 3.3 Sorption curves of mixtures; additivity and potential interactions - 3.4 Mathematical modeling of sorption isotherms - 3.5 Kinetics of the sorption phenomenon	
4. Functional properties of absorbed water	117
4.1 Solvent power of water - 4.2 The freezability of water - 4.3 Mobility of water molecules - 4.4 Density of adsorbed water - 4.5 Calorimetric properties - 4.6 Quantitative comparison of the different forms of water	
Conclusion	121
Appendix 1	130
1. Concept of the activity of water (a_w) - 2. Water activity and vapor pressure - 3. Activity of water in a solution - 4. Water activity, osmotic pressure and capillary pressure - 5. Relation between a_w and temperature	
Appendix 2	134
Appendix 3	136
3 HEAT AND MOISTURE TRANSFER IN GRAINS, CONSEQUENCES FOR AERATION AND STORAGE, by L. Bounnas	160
1. General comments	160
2. Transfer of heat and moisture between grains and air	160
3. Study of a simplified model of heat and moisture transfer in an aerated bin	163
4. Comments on these results	166
5. Adaptation of this model to the practical problems of grain storage .	167
Conclusions	168
4 PRESSURE DROPS DUE TO UNIDIMENSIONAL AIR FLOW THROUGH GRAIN MASSES, CONSEQUENCES IN AERATION, by S. Sraur	170
1. Pressure drop due to the grain	170
1.1 Influence of the type of grains - 1.2 Influence of bulk density - 1.3 Influence of air speed - 1.4 Influence of grain height	
2. Measurement of pressure drops	177
2.1 Experimental set-up - 2.2 Methodology - 2.3 Measurements performed - 2.4 Flow equation and discussion of results - 2.5 Estimation of unit pressure drops for different bulk densities	
3. Consequences in ventilation	179
3.1 Pressure drops due to the air distribution system - 3.2 Pressure drops due to the air diffusion system in the grain - 3.3 The total pressure drop of an installation - 3.4 Choice of fan	
Appendix : Correspondence between units	187
5 THERMAL PROPERTIES OF GRAINS, PRODUCTION OF HEAT AND CO_2 , by S. Sraur . .	189
1. Factors acting on the production of heat and carbon dioxide	189

1.1 Action of temperature - 1.2 Action of moisture - 1.3 Influence of time of harvesting - 1.4 Bin storage with microfloral development	
2. Formulae for carbon dioxide release	191
3. Temperature variation of a poorly ventilated grain mass	191
3.1 First form - 3.2 Second form - 3.3 Time multiplication coefficients for different moisture contents	
4. Numerical data for the release of heat and carbon dioxide	195
5. Applications	197
5.1 Maize - 5.2 Wheat - 5.3 Maize	
6. Conclusions	198

PART II - BIOLOGY OF GRAINS AND SEEDS IN THE POST-HARVEST ECOSYSTEM 203

6 SEEDS, ORGANS OF SURVIVAL, by D. Côme	205
1. Organs of resistance	205
1.1 Seed structure - 1.2 Biology of dry seeds : suspended life - 1.3 Special case of seeds which do not tolerate desiccation	
2. Seed survival	206
2.1 Lifespan of seeds - 2.2 Origin of seed death - 2.3 Prolongation of viability - 2.4 Tests of viability and vigor	
3. Dormancies	213
3.1 Diverse types of dormancy - 3.2 Principal characteristics of dormancy	
3.3 Elimination of dormancy	
4. Conclusions	221
7 GENERAL CHARACTERISTICS OF THE MICROFLORA OF GRAINS AND SEEDS AND THE PRINCIPAL RESULTING SPOILAGES, by D. Richard-Molard	226
1. Microorganisms	227
1.1 Bacterial flora - 1.2 The molds - 1.3 The yeasts	
2. Elements of microbial physiology and biochemistry	235
2.1 Biological oxidations. Respiratory types - 2.2 Carbohydrate breakdown	
2.3 Lipid breakdown - 2.4 Protein breakdown - 2.5 Anabolic reactions. Microbial biosyntheses	
Conclusions	240
8 ECOLOGY OF THE MICROFLORA OF GRAINS AND SEEDS, by J. Pelhate	244
1. Floristic succession	244
1.1 Inventory methods - 1.2 Static aspect of the flora : floristic successions	
2. Dynamic series	251
2.1 Demonstration of a normal floristic succession - 2.2 Ecological determinism - 2.3 Practical applications	
9 EFFECTS OF GRAIN "STABILIZATION" PROCESSES, by J. Poisson and B. Cahagnier	263
1. Influence of the initial quality of the grains on the growth of their microflora	263
1.1 Impurities - Mechanical damage - 1.2 Early fungal attack - 1.3 Grain ripeness - 1.4 Contamination of material and storage areas	
2. Control of microorganismal growth by regulation of environmental conditions	266
2.1 Traditional techniques - Air storage - 2.2 Modified atmosphere storage	
3. Chemical and physical treatments	271
3.1 Physical treatments - irradiation - 3.2 Chemical treatments	
Conclusions	284

10	CLASSIFICATION AND CHEMICAL CHARACTERISTICS OF FUNGAL TOXINS IN GRAINS AND SEEDS, by C. Frayssinet	290
	1. Aflatoxins	290
	1.1 Discovery and producing strains - 1.2 Structure - 1.3 Physicochemical properties - 1.4 Metabolism - 1.5 Toxicity - 1.6 Contamination	
	2. Epoxytrichothecenes	293
	2.1 Chemical structure - 2.2 Physicochemical properties - 2.3 Toxic properties - 2.4 Immunosuppressive capacity - 2.5 "Refusal factor" and vomitoxin - 2.6 Action mechanism of trichothecenes - 2.7 Contamination	
	3. Zearalenone	297
	3.1 Structure - 3.2 Biological properties - 3.3 Contamination	
	4. Ochratoxins	299
	4.1 Producing strains and structure - 4.2 Physicochemical properties - 4.3 Toxic properties - 4.4 Contamination	
	5. Citrinin	301
	6. Patulin	302
	6.1 Structure and producing strains - 6.2 Toxic properties - 6.3 Effects on humans - 6.4 Contaminations	
	7. Sterigmatocystine	304
	7.1 Physicochemical - 7.2 Structure - 7.3 Metabolism - 7.4 Toxicity - 7.5 Contamination	
11	MICROBIOLOGY OF SEEDS IN RELATION TO CONDITIONING : ITS INFLUENCE ON GERMINATIVE CAPACITY, by J. Pelhate	310
	Introduction	310
	Biological quality of seeds - Spoilage spermo <i>fl</i> ora	
	1. Ecological behavior of seed myco <i>fl</i> ora	311
	1.1 Ecological complex : seed + myco <i>fl</i> ora - 1.2 Spermoflora dynamics	
	2. Spoilage of stored seeds	314
	2.1 Demonstration - 2.2 Spoilage effects	
	3. Application to integrated control	318
	3.1 Seed health test - 3.2 Ecological control of conditioning - 3.3 Genetic improvement - 3.4 Treatment of seeds	
	Conclusions	321
12	MICROBIOLOGY OF MOIST GRAINS, by J. Pelhate	328
	1. Delayed drying of damp grains	328
	1.1 Treatment of grain by chemical stabilizers - 1.2 Airtight storage	
	2. Slow drying of grains	330
	2.1 Air storage, without active ventilation - 2.2 Drying by aeration	
	3. Storage of moist grains	338
	3.1 Storage of untreated grains - 3.2 Silage of ground grain	
	Conclusions	342
13	TOXIGENESIS AS A FUNCTION OF THE ECOLOGICAL CONDITIONS OF THE GRAIN/MICRO-ORGANISMS SYSTEM, by J. Le Bars	347
	1. Origin of toxins resulting from the development of molds	347
	1.1 Principal elaboration mechanisms of zootoxic metabolites - 1.2 Biogenetic origin of mycotoxins	
	2. Toxigenesis : general data	350
	2.1 Intrinsic factors - 2.2 Extrinsic factors	
	3. Natural occurrence of mycotoxins in grains and seeds	357
	3.1 Aflatoxins - 3.2 Zearalenone - 3.3 Ochratoxin A - 3.4 Other mycotoxins	
	Conclusions	359

14	INSECTS, by F. Fleurat-Lessard	367
	1. Introduction	367
	1.1 General comments - 1.2 Extent of losses due to insects - 1.3 Sources of contamination	
	2. General features of grain and seed insects	369
	2.1 General comments - 2.2 Schematic morphology and internal organization	
	2.3 General characteristics and growth cycles of the principal orders -	
	2.4 Appearance of insect damage and summary identification	
	3. Description and biology of injurious species	378
	3.1 Grain Coleoptera - 3.2 Grain Lepidoptera	
15	GRAIN MITES, GENERAL CHARACTERISTICS AND CONSEQUENCES OF THEIR PRESENCE IN STOCKS, by F. Fleurat-Lessard	409
	1. General characteristics of the mites of stocks	409
	1.1 Anatomy - 1.2 General biology	
	2. Principal injurious species	411
	2.1 Saprophytic mites - 2.2 Predatory or parasitic mites	
	3. Risks linked to pullulations of mites	414
	4. Conclusions	415
16	VERTEBRATE PESTS OF STORED GRAINS AND SEEDS, by G. Grolleau and P. Gramet	417
	1. General introduction	417
	2. Rodent depredators of stocks	419
	2.1 Preliminary remarks 2.2 Nature and economic importance of the damage	
	2.3 The species - 2.4 Control techniques - 2.5 Practical implementation of control measures	
	3. General conclusions	432
PART III - ANALYTICAL METHODS FOR THE INTRINSIC TESTING OF GRAINS AND SEEDS IN THE POST-HARVEST SYSTEM		435
17	INSPECTION OF GRAINS AND SEEDS AT THE ELEVATOR, by C. Mauzé	437
	1. General examination - organoleptic characteristics	437
	1.1 Applications - 1.2 Method	
	2. Mass per hectoliter	438
	2.1 Definitions - 2.2 Application - 2.3 Methods - 2.4 Significance of the results - 2.5 Mass per hectoliter and storage	
	3. Determination of besatz (impurities)	440
	3.1 Definitions - 3.2 Application - 3.3 Methods - 3.4 Impurities and storage	
	4. Other storage analyses	444
	4.1 Hagberg test - 4.2 Acidity - 4.3 Germination test	
	5. Conclusions	445
18	SAMPLING OF GRAINS AND SEEDS, METHODS AND MEANS, by M.F. Beaux	446
	1. Theoretical objectives	446
	1.1 Some definitions - 1.2 What is a good sample ? - 1.3 How to obtain a good sample ?	
	2. Practical realization	448
	2.1 Sampling - 2.2 Dividing	
	3. Opt for mechanical systems	453
19	STANDARD METHODS FOR THE MEASUREMENT OF MOISTURE CONTENT OF GRAINS AND SEEDS, by J.L. Multon and G. Martin	454

1.	Standardization of reference methods for the determination of moisture content	455
2.	Principles of the reference methods in the case of grains and seeds	459
2.1	<i>The problem of grinding and pre-drying</i> - 2.2 <i>Standardization reference methods</i> - 2.3 <i>Approximate methods</i>	
3.	Repeatability of moisture measurement methods : theoretical calculations and experimental evaluation	
4.	Reproducibility	463
20	RAPID MOISTURE MEASUREMENT UPON RECEPTION AT THE STORAGE AGENCY, by G. Martin and J.L. Multon	466
1.	The different types of moisture meters	467
1.1	<i>High-temperature drying methods</i> - 1.2 <i>Instruments which measure a physical quantity</i>	
2.	Regulations and endorsed instruments	469
2.1	<i>General principles of the regulations</i> - 2.2 <i>Endorsed instruments</i>	
3.	The limits of current rapid methods	474
	Conclusions	475
21	QUANTITATIVE AND QUALITATIVE MICROBIOLOGICAL ANALYSES (BACTERIA, YEASTS, MOLDS), by B. Cahagnier and J. Poisson	477
1.	Sampling	478
2.	Enumeration methods	479
2.1	<i>"Direct observation" methods of fungal flora</i> - 2.2 <i>Enumeration after suspension of grain microorganisms (molds, yeasts, bacteria)</i>	
3.	Methods for the estimation of the fungal biomass of grains	487
3.1	<i>Assay of a specific fungal constituent</i> - 3.2 <i>Detection of the biomass by immunofluorescence</i> - 3.3 <i>Detection of the biomass by spectrofluorimetry</i>	
4.	Determination of a specifically microbial, biological or metabolic activity, or a product thereof.	490
4.1	<i>Production of volatile compounds</i> - 4.2 <i>Release of fatty acids</i>	
	Conclusions	491
22	DETERMINATION OF INSECT INFESTATION, by F. Fleurat-Lessard	495
1.	Introduction	495
2.	The taking of samples for entomological analysis	495
2.1	<i>Brief reminder of definitions</i> - 2.2 <i>Principles of sampling</i> - 2.3 <i>General infestation survey</i> - 2.4 <i>Detection and measurement of insect infestation in a grain mass, sampling procedure</i>	
3.	Methods for the detection of insects in an elementary sample	502
3.1	<i>Detection of free forms : initial visible infestation</i> - 3.2 <i>Detection of hidden forms</i>	
	Conclusions	512
23	DETECTION OF PESTICIDE RESIDUES, by M. Hascoet	516
1.	Sources of contamination	516
1.1	<i>Crop treatment</i> - 1.2 <i>Storage treatments</i> - 1.3 <i>Eradication treatments : the fumigants</i>	
2.	Assay methods	518
3.	Sampling and sample storage	518
3.1	<i>Extraction</i> - 3.2 <i>Purification</i> - 3.3 <i>Assaying</i>	
4.	Multidetection method applicable to organochlorine (OC) and organophosphorus (OP) pesticides	521
4.1	<i>Principle</i> - 4.2 <i>Equipment</i> - 4.3 <i>Solvents and reagents</i> - 4.4 <i>Experimental procedure</i>	

5. Multidetecion method applicable to halogenated organic fumigants -	524
6. Hydrogen phosphide assay - 7. Inorganic bromide assay	525
8. Conclusions	
24 DETECTION AND ASSAY OF TOXINS IN GRAINS AND SEEDS, by C. Frayssinet and B. Cahagner	527
1. Aflatoxins	528
1.1 Sample preparation - 1.2 Rapid minocolumn method - 1.3 Technique applicable to simple foods - 1.4 Use of High performance liquid chromatography (HPLC) - 1.5 Rapid method for the detection of aflatoxin in maize	
2. Zearalenone assays	535
2.1 EPPLEY'S technique (1968) - 2.2 Technique due to MIROCHA, SCHAUERHAMER and PATHRE (1974) - 2.3 Use of High pressure liquid chromatography (HPLC)	
3. Assays of epoxytrichothecenes	538
3.1 Biological test based on dermatonecrotic properties - 3.2 Technique of ROMER, BOLING and Mc DONALD (1978)	
4. Desoxynivalenol or vomitoxin (MIROCHA'S technique)	542
4.1 Extraction - 4.2 Purification of the extract - 4.3 Chromatography on a thin layer of silica gel - 4.4 Gas chromatography	
5. Patulin assay	543
5.1 Technique of SCOTT and KENNEDY (1973) - 5.2 Thin layer chromatography	
5.3 Use of high performance liquid chromatography	
6. Assay of ochratoxins	546
6.1 Preparation of standard solutions - 6.2 Extraction - 6.3 Purification of ochratoxins - 6.4 TLC	
7. Assay of sterigmatocystine	547
7.1 Preparation of standard solutions - 7.2 Extraction - 7.3 Preliminary TLC - 7.4 Column purification	
8. Remarks	548
PART IV - POST-HARVEST TECHNOLOGIES	551
25 GRAIN HANDLING IN STORAGE AGENCIES, by G. Renaud	553
1. A handling machine is not isolated in the world	553
2. French experience in silos and handling	555
3. What handling machinery ?	564
4. Techniques connected with handling and their evolution	564
4.1 Sacks - Bulk cars - Trucks - Tipping devices - Shovels - 4.2 Emptying devices for flat-bottomed storage bins - 4.3 Weighing of grain - 4.4 The cleaning of grains - 4.5 Problems posed by dust - Removal of waste - 4.6 Problems of remote control and centralization - 4.7 Grain storage - Air delivery - Silo-thermometry	
5. Handling devices	579
5.1 Gravity handling - 5.2 Horizontal handling - 5.3 Vertical handling - 5.4 Oblique handling - 5.5 Pneumatic transport - 5.6 Harbor cranes (traveling gantries) for the loading and unloading of grain ships - 5.7 Loading of grain cars by shuttle belt conveyor	
26 THE DRYING OF GRAINS, PRINCIPLES, EQUIPMENT, ENERGY SAVINGS AND FIRE SAFETY, by J.C. Lasseran	606
Introduction	606
1. General principles of drying	607
1.1 Drying technique and agricultural products - 1.2 Characteristics of maize grain - 1.3 Simplified theory of the drying of grains	
2. Technical characteristics of driers	633
2.1 In-bin drying - 2.2 Closed-circuit grain-recirculation driers - 2.3 Continous flow driers - 2.4 Drying fuels and heater-blower units	

3.	Energy savings in the drying of grain	646
3.1	<i>Thermal balance sheet for conventional driers - 3.2 Existing energy-saving procedures - 3.3 A new energy, the biomass</i>	
4.	Fire safety at drying installations	656
4.1	<i>Fires - 4.2 Fire prevention</i>	
27	THE AERATION OF GRAINS AND THE MEASUREMENT OF GRAIN TEMPERATURE IN STORAGE BINS (SILO-THERMOMETRY), by J.C. Lasseran	664
	Introduction : Definition of aeration of grains	664
1.	General data on grain aeration	666
1.1	<i>Theoretical aspects - 1.2 Study of the phenomena of cooling and drying of grain by aeration - 1.3 Drying aeration or ventilation - 1.4 Adaptation of solar energy to ventilation</i>	
2.	Bases for calculations related to aeration installations	701
2.1	<i>Air flow as a function of grain type and moisture content - 2.2 Fans</i>	
2.3	<i>Pressure drops</i>	
3.	Setting up aeration installations	717
3.1	<i>Total air flow - 3.2 Air distribution systems - 3.3 Special cases of difficult aeration</i>	
4.	The measurement of grain temperature in storage bins (silo-thermometry).	730
4.1	<i>General principle - 4.2 Equipment - 4.3 Use of silo-thermometry</i>	
5.	Management of cooling by aeration	735
5.1	<i>Reminders of fundamental notions about aeration - 5.2 Rational management of aeration - 5.3 Aeration tests</i>	
28	MODIFIED ATMOSPHERE STORAGE OF GRAINS, by J. Shejbal and J.N. de Boislambert	749
1.	Introduction	749
2.	Airtight storage	750
2.1	<i>Principles and scope - 2.2 Underground stores - 2.3 Above-ground stores</i>	
3.	Controlled atmosphere storage	756
3.1	<i>Principles and scope - 3.2 Storage structures, desinestation and preservation techniques</i>	
4.	Economics of modified atmosphere storage of grains	768
29	THE TECHNOLOGY OF SILO CONSTRUCTION IN EUROPE, by M. Reimbert and A. Reimbert	778
	Introduction - Historical perspective	778
	Principal categories of silos	778
	WALLS OF TYPE "a" : <i>Permitting air circulation through the walls</i>	780
	WALLS OF TYPE "b" : <i>Resistant to rainwater</i>	783
	WALLS OF TYPE "c" : <i>Impermeable to water and air or gas</i>	798
	WALLS OF TYPE "d" : <i>The face of the walls in contact with the ensiled material is accepted as constructed</i>	807
	WALLS OF TYPE "e" : <i>With perfectly smooth internal surface</i>	808
	WALLS OF TYPE "f" : <i>Thermally insulated</i>	809
	WALLS OF TYPE "g" : <i>Coated</i>	810
	Vertical silos and horizontal silos	811
	Various precautions	812
	Calculations	813
30	DETOXIFICATION OF STOCKS INTENDED FOR ANIMAL FEED, by G. Viroben	818
1.	Introduction	818
2.	Technique for the decontamination of agricultural products polluted by aflatoxin	819
2.1	<i>Decontamination of the peanut - 2.2 Decontamination of maize</i>	
3.	Conclusions	828

31	CHEMICAL CONTROL OF STORED FOODSTUFF INSECTS, by R. Pierrot	832
	1. Removal of insects and protection of cereals	832
	1.1 The use of contact insecticides - 1.2 Treatment by fumigation - 1.3 Choice of treatment process	
	2. Purging storage bins of insects	840
	2.1 Elementary precautions - 2.2 Treatment using contact insecticides - 2.3 Fumigation treatments	
32	THE CHARACTERISTICS OF GRAIN DUST AND THE PREVENTION OF GRAIN DUST EXPLOSIONS IN SILOS, by J. Burč	843
	1. Grain dust in processing and storage centers	844
	1.1 Dust concentration - 1.2 Average size of particles ; total surface area ; velocity at which the dust is captured ; settling time - 1.3 Chemical composition - 1.4 The physical characteristics of grain dust - 1.5 The rheological properties of grain dust - 1.6 The microbial flora of grain dust in silos	
	2. Explosive power of grain dust	846
	2.1 Ignition temperature - 2.2 The minimum energy required to ignite grain dust - 2.3 Minimum explosive concentration - 2.4 The minimum explosive mass - 2.5 The risk of explosion due to various dusts	
	3. Grain dust explosions	852
	3.1 The course of a dust explosion - 3.2 Estimating the risks of dust explosions according to the type of dust - 3.3 Various causes for the triggering of grain dust explosions - 3.4 Is the electrostatic triggering of grain dust explosions a real risk ?	
	4. Reducing the effects of grain dust explosions	859
	4.1 Reducing the formation of dust - 4.2 Prevention of explosions by physicochemical methods - 4.3 How to control insects that generate grain dust - 4.4 Equipment for the control of grain dust - 4.5 Improving the equipment for the collection of dust and improving the quality of air in grain storage facilities - 4.6 Transporting and stocking dust	
	5. Improvement of safety in grain processing	863
	5.1 Prevention of explosions using thermographic detection - 5.2 Limiting damage in the course of silo explosions by weakening resistance points - 5.3 Improvement of silo equipment to ensure personnel safety - 5.4 Causes of grain silo explosions - 5.5 Detecting and eliminating grain dust explosions - 5.6 Strategies for improving safety in grain processing - 5.7 Standards for monitoring the air in grain silos and for reducing (or even eliminating) grain dust explosions	
	6. Government measures to prevent grain dust explosions in the U.S. . . .	868
	6.1 U.S.D.A. safety recommendations - 6.2 U.S.D.A. analysis of damage from grain dust explosions - 6.3 U.S.D.A. and O.S.H.A. research programs	
	7. Uses of grain dust in the united states	870
	7.1 Grain dust used in cattle feed - 7.2 Incineration of grain dust - 7.3 Use of grain dust for compost - 7.4 Bioconversion of grain dust	
	8. Do silo explosions constitute a special risk in the unites states? . .	871
	8.1 Grain processing in American silos - 8.2 Remark	
	9. Conclusions : Directions for further research to reduce the risks of silo explosions in France	872
33	THE PREVENTION OF ACCIDENTS IN STORAGE INSTALLATIONS, by J.L. Poichotte .	881
	1. Accidents involving falls, engulfment or asphyxia	881
	1.1 The causes of accidents - 1.2 Arrangements for ensuring the normal flow of materials - 1.3 Material arrangements for preventing staff from entering storage recipients - 1.4 Instructions for performing work inside material accumulators	
	2. Risks of accidents upon the reception of grain	885
	3. Electrical risks	886
	Use of portable material	

PART V - INFLUENCE OF DRYING AND STORAGE CONDITIONS ON THE TECHNOLOGICAL AND NUTRITIONAL QUALITIES OF GRAINS AND SEEDS	887
34 THE METABOLISM OF LIPIDS, ENZYMATIC AND NON-ENZYMATIC AUTOXIDATION, by R. Guillaumin	889
1. Introduction	889
1.1 The importance of lipids - 1.2 Distribution of lipids in the plant kingdom - 1.3 Fatty acid composition of plant lipids - 1.4 Transformations undergone by lipids	
2. Hydrolysis of lipids	893
2.1 Action of lipolytic enzymes - 2.2 Consequences of the presence of lipases on grains and seeds - 2.3 The origin of lipases - 2.4 Mode of action of lipases	
3. Enzymatic oxidation	895
3.1 Action of lipoxygenase - 3.2 Mechanism of enzymatic oxidation by lipoxygenases - 3.3 Sources of lipoxygenase - 3.4 Enzymatic activity - 3.5 Enzymatic oxidation reaction kinetics - 3.6 By-products of enzymatic oxidation - 3.7 The consequences of oxidation by lipoxygenase	
4. Non-enzymatic autoxidation	901
4.1 Lipid oxidation products - 4.2 The peroxides - 4.3 Mechanism of the formation of hydroperoxides - 4.4 Peroxidation of various unsaturated fatty acids - 4.5 Mechanism of the formation of cyclic peroxides - 4.6 Initiation mechanism - 4.7 Evolution of peroxides	
35 CHANGES IN GRAIN CARBOHYDRATE COMPOSITION DURING STORAGE, by M.T. Tollier	911
1. Materials and methods	911
2. Results and discussion	912
2.1 Changes in the carbohydrate fraction and the α -amylase activity as a function of drying conditions - 2.2 Changes in the carbohydrate fraction and the α -amylase activity as a function of pre-storage conditions - 2.3 Changes in the carbohydrate fraction and the α -amylase activity of maize pre-stored and then dried at different temperatures	
Conclusions	917
36 RISKS OF MYCOTOXICOSES IN HUMANS AND ANIMALS, by P. Lafont and J. Lafont	921
1. Human mycotoxicoeses	921
1.1 Ergotism - 1.2 Alimentary toxic aleukia (A.T.A.) - 1.3 Aflatoxicoeses - 1.4 Other mycotoxicoeses	
2. Animal mycotoxicoeses	925
2.1 Aflatoxicoeses - 2.2 Fusariotoxicoeses - Stachybotriotoxicoeses - Dendrodochitoxicoeses - 2.3 Ochratoxicoeses - 2.4 Estrogenic syndrome due to zearalenone - 2.5 Other mycotoxicoeses	
3. Prophylaxis	930
37 THE NUTRITIONAL VALUE OF CEREALS FOR ANIMAL FEED : THE EXAMPLE OF MAIZE, A.M. Aumaitre	936
1. Introduction	936
2. Changing factors in the quality of maize grain	938
2.1 The chemical composition of immature maize and of mature maize - 2.2 Storage of wet maize grain in a silo - 2.3 The effect of drying on maize	
3. Conclusions	947
38 WET-MILLING QUALITY OF MAIZE AND RATING METHODS, by V. Beaux and A. Lebras	949
1. Criteria of wet-millability	949
2. Composition of maize grain	950

3.	Effects of storage conditions on wet-milling quality	951
4.	Effects of drying conditions on wet-milling quality	952
4.1	<i>Consequence of drying on the physical appearance of the grain - 4.2</i>	
	<i>Effects of drying on grain constituents and chemical components - 4.3</i>	
	<i>Influence of temperature, heated air flow rate and initial moisture content</i>	
	<i>(in a pilot installation) - 4.4 Influence of the type of drying (indus-</i>	
	<i>trial type) - 4.5 Influence of drying on different types of grain - 4.6</i>	
	<i>Influence of drying in cribs</i>	
5.	Tests and rapid analyses for assessment of wet-milling quality	955
5.1	<i>Tests of dry characteristics - 5.2 Water uptake tests - 5.3 Tests of</i>	
	<i>biophysical structure</i>	
6.	Simple correlation and prediction equations	959
7.	Conclusions	961
39	TECHNOLOGICAL VALUE OF OLEAGINOUS GRAINS (SEEDS AND OIL PRODUCTS), <i>by</i>	
	<i>P. Burghart</i>	963
1.	The drying of grains for crushing	963
1.1	<i>Breakage and splitting of grains - 1.2 Degradation of grain consti-</i>	
	<i>tuents - 1.3 Practical drying conditions</i>	
2.	Drying of oleaginous seeds	965
2.1	<i>Drying of rapeseed - 2.2 Drying of sunflower seeds - 2.3 Drying of</i>	
	<i>soybeans</i>	
3.	Storage of oleaginous grains	974
40	MILLING VALUE AND BAKING QUALITY OF SOFT WHEATS AND THEIR FLOURS, <i>by</i>	
	<i>B. Godon</i>	978
1.	Drying and storage conditions for wheats and flours	978
2.	Methods for testing the milling and baking qualities of wheats and flours	979
3.	Biochemical bases of milling and baking quality	981
4.	Influence of the drying and storage of grains	982
4.1	<i>Drying - 4.2 Storage of grains</i>	
5.	Influence of the drying and storage of flours	987
5.1	<i>Drying of flours - 5.2 Storage of flours</i>	
41	THE VALUE OF DURUM WHEATS IN THE MAKING OF SEMOLINA AND PASTA PRODUCTS,	
	RATING METHODS, <i>by</i> <i>E. Trentesaux</i>	996
42	THE EFFECT OF STORAGE ON THE TECHNOLOGICAL VALUE OF BREWER'S BARLEY, <i>by</i>	
	<i>R. Scriban</i>	1001
1.	Introduction	1001
1.1	<i>General definition of brewer's barley - 1.2 The importance of brewer's</i>	
	<i>barley in the world, in the EEC, and in France - 1.3 The importance of the</i>	
	<i>technological quality of barley</i>	
2.	The influence of drying on brewer's barley	1002
2.1	<i>Biochemical effects of drying on barley - 2.2 Biological effects of</i>	
	<i>the drying process</i>	
3.	Effects of storage on barley	1006
	Conclusions	1008
43	THE GERMINATIVE VALUE OF SEEDS, <i>by</i> <i>H.A. Renard</i>	1011
	Introduction	1011
1.	Effect of storage and drying conditions on mechanisms for protection	
	against precocious germination	1012
2.	The phenomenology of aging	1013

2.1 Functional elements : effectors of metabolism and cellular ultra-structures - 2.2 The genetic elements - 2.3 Manifestations of aging, possible criteria of deterioration	
3. Implementation of storage	1022
3.1 The causes of variation at the level of the seed - 3.2 Action of temperature and humidity ; modelling tests - 3.3 Limiting conditions in the lowering of moisture content and temperature - 3.4 Storage under anaerobic conditions - 3.5 Succinct storage practice	
4. Influences of drying conditions	1031
4.1 General principles - 4.2 Application of general data to some representative species	
5. Can the storability of batches be determined ?	1039
PART VI - STORAGE SPECIFICATION IN TROPICAL CLIMATES	1049
44 THE STORAGE OF CEREALS IN THE DEVELOPING COUNTRIES OF THE TROPICAL ZONE, by F. Troude	1051
1. Specific of storage in tropical zones	1051
1.1 Tropical climates - 1.2 Nature and quality of stored grains - 1.3 Socio-economic conditions in developing countries	
2. Orientation of techniques	1053
2.1 Traditional storage - 2.2 Centralized storage	
45 CHEMICAL PROTECTION OF GRAINS IN TROPICAL CLIMATES, by P. Ducom	1057
1. Influence of the tropical environment on the fauna, grains and pesticides	1057
1.1 The tropical environment - 1.2 Influence on the fauna - 1.3 Influence on the foodstuff - 1.4 Influence on pesticides - 1.5 Consequences of the practices	
2. Insecticide treatments	1060
2.1 The panoply of useful insecticides - 2.2 Presentation of insecticides	
2.3 Treatment techniques	
3. Grain protection systems	1063
3.1 Protection at the farm level - 3.2 Large-scale storage protection	
46 TECHNOLOGICAL VALUES OF CEREALS IN HOT COUNTRIES : RICE, MILLET, SORGHUM, by B. Pons-Matignon	1067
APPENDIX A : THE FRENCH OFFICE OF WEIGHTS AND MEASURES, by R. Estival, J. B Boesch, P. Russac and Ferrec	1073
1. The role of the french office of weights and measures	1073
2. Legal metrology. Metrological departments in different countries. International metrology organizations (O.I.M.L., E.E.C.)	1074
2.1 Legal Metrology - 2.2 Metrology agencies in different countries - 2.3 The International Organization of Legal Metrology (I.O.L.M.) - 2.4 The European Economic Community	
3. The role of the french bureau of weights and measures in the food and grain industry	1076
4. The aim of the apparatus and the units of measure used	1076
4.1 Saccharimeters - 4.2 Moisture Meters - 4.3 Refractometers - 4.4 Alcohol Meters and Hydrometers for Alcohol	
5. Testing weighing and measuring equipment subject to government regulation	1078
5.1 Approbation - 5.2 Initial verification - 5.3 Periodic verification	
6. Yearly inspection of apparatus	1079
6.1 Saccharimeters - 6.2 Refractometers - 6.3 Moisture meters	

APPENDIX B : INTERNATIONAL STANDARDIZATION AND STORAGE, by E. Nouat	1083
1. The different organizations	1083
2. The tasks of the ISO	1085
Published standards	1087
<i>Standards drawn up by working group 2 "Storage" of ISO/TC 34/ SC 4</i>	
<i>"Cereals and pulses"</i>	
<i>Other standards drawn up by the ISO : Mycotoxins - Microbiology - French</i>	
<i>standardization</i>	
APPENDIX C : GROUP FOR ASSISTANCE ON SYSTEMS RELATING TO GRAIN AFTER-HARVEST (GASGA)	1089
INDEX	1091