MOISTURE EQUILIBRIUM IN RELATION TO THE CHEMICAL STABILITY OF DEHYDRATED FOODS, A BIBLIOGRAPHY

by

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INTRODUCTION

The general relationship between moisture equilibrium and the stability of stored food has long been recognized by food technologists. In recent years, however, this relationship has come under intensive study with the result that a large body of data has been developed pertaining to various foods under different conditions. In this research the effects of moisture on the chemical, enzymatic, and microbiological activity in the stored foods have been reported sometimes separately, sometimes jointly. The present bibliography attempts to bring together those references on moisture equilibrium which bear on chemical stability. But while the scope is thus limited, the list necessarily includes some references treating of enzymatic and microbiological phenomena, as well as other related studies in moisture equilibrium.

Principal sources for the references were Chemical Abstracts, Dairy Science Abstracts, and the Abstract Section of Journal of the Science of Food and Agriculture. All articles consulted were checked for useful additional citations not found in the general search. Thus, significant references as early as 1921 have been included.

References are arranged alphabetically by first author and numbered consecutively. All authors are included in an author index. A subject index is also provided, and both indexes refer to items by their assigned number.

We are grateful to Dr. John G. Kapsalis and his associate, Mrs. Margaret Driver, both of the Food Division, for their valuable assistance.

CONTENTS

PART I. REFERENCES

1. ANONYMOUS
Dehydrated meat. Food (London) 27(321):218. 1958.

Studies with freeze-dried beefsteaks and pork chops show that stability of vitamins in them is as good as, if not better than, that in fresh beef and pork. Specific conclusions are given in detail. (From Nat. Agric. Lib., Library List No. 77, 1963)

2. ACKER, LUDWIG.
Enzymic reactions in foods of low moisture content. Advances in Food Research 11:263-330. 1962.

Comprehensive review of literature available on enzymic changes in different foods; on the elucidation of certain spoilage processes; on the relation between the moisture content of such foods and their susceptibility to enzymic reactions and on some theories that will explain the mechanism of enzymic action. Period: 1918 to 1962. Enzymes mentioned: lipase, phosphatase, catalase, peroxidase, proteaser, phospholipase, lipoxidase, phytase, phenoloxidases.

3. _____and LÜCK, E.
Über den Einfluss der Feuchtigkeit auf den Ablauf enzymatischer Reaktionen in wasserarmen Lebensmitteln. (Influence of moisture on course of enzymic reactions in food.) Z. Lebensm. Untersuch. Forsch. 108:256-269, 1958.

Curves showing the course of the decomposition of lecithin in dough and cereal mixtures with egg-yolk at 25° under different R.H. (5-75%) all tend to reach maximum values (depending on the R.H.) within 30-40 days. With increasing R.H. $<$60-65%, the increases in the maximum are slow; at R.H. $>$60-65%, the increases are rapid. The points of upward inflexion in the curves correspond with the R.H. at which active absorption of moisture by the samples commences. The enzymic action appears to depend almost entirely on the presence of adsorbed capillary moisture. (From J. Sci. Food Agric. abstr. 1959, i-232)

4. ADAMSON, ARTHUR W.
Adsorption of gases and vapors on solids; the surface area of solids. In Physical Chemistry of Surfaces. (New York, Interscience Publishers) Chapter XI, p.457-529, 1960.

The author discusses and compares the derivation, properties and modifications of the Langmuir, Freundlich, and B.E.T. (Brunauer-Emmet-Teller) adsorption isotherms and compares the surface areas from various models.

5. AMBERG, C. H.
Heats of adsorption of water vapor on bovine serum albumin.
J. Am. Chem. Soc. 79:3980-3984. 1957.

Heats of adsorption of water vapor on bovine serum albumin were measured calorimetrically at 20° and are presented together with the isotherms. The heat curves are discussed and critically compared with calculated values from the literature. Possible mechanisms for the adsorption process are considered, with special regard to the high initial heats and the appearance of a maximum in the heat-coverage curve near the B.E.T. value for a complete monolayer.

6. ANET, E. F. L. J. and REYNOLDS, T. M.
Chemistry of non-enzymic browning. I. Reactions between amino acids, organic acids, and sugars in freeze-dried apricots and peaches. Australian J. Chem. 10:182-192. 1957.

The water-soluble constituents of apricot and peach purées were examined qualitatively and quantitatively before and after storage for 4 to 16 months at 25°C and 70% R.H. All samples contained all the amino acids, organic acids, sugars, and polyols previously detected (Reynolds 1957; Anet and Reynolds 1955a, 1955b; Ash and Reynolds 1955a, 1955b) in the two species of fruit.

The stored samples also contained the following compounds: eleven 1-(N-amino acid)-1-deoxyfructoses, traces of two 2-(N-amino acid)-2-deoxyglucoses, nine by-products of unknown constitution formed from the reaction between glucose and aspartic acid and glucose and asparagine, three compounds formed from ammonia and glucose, two series of sucrose, glucose, and fructose mono-esters of malic acid, traces of a sorbitol mono-ester of malic acid, and some sugar mono-esters of citric acid.

The free amino acid or organic acid lost was equal, on a molar basis, to the amino acid-deoxyfructoses (and related compounds) and sugar esters formed. After allowing for these derivatives as much as 7 percent of the total sugar (calculated as hexoses) originally present could not be accounted for.

7. _____ and REYNOLDS, T. M.

Chemistry of non-enzymic browning. II. Some crystalline amino acid-deoxy-sugars. Australian J. Chem. 10:193-197. 1957.

From the reactions of glycine with glucose, fructose, and xylose, 1-deoxy-1-glycino-d-fructose, 2-deoxy-2-glycino- -d-flucose, and 1-deoxy-1-glycino-d-threopentulose respectively have been isolated pure and crystalline. Similarly glucose and β-alanine gave 1-β-alanino-1-deoxy-d-fructose.

8. ANET, E. F. L. J. and REYNOLDS, T. M.
Reactions between amino-acids, organic acids, and sugars in freeze-dried apricots. Nature 177(4519):1082-1083. 1956.

Freeze-dried apricot puree, stored at 25°C, and 70 percent relative humidity for 16 months, became mid-brown in color. Other characteristic changes are described. (From Nat. Agric. Lib., Library list no.77, 1963)

9. ANGLEMIER, A. F., CRAWFORD, DAVID L., and SCHULTZ, H. W.
Improving the stability and acceptability of precooked freeze-dried ham. Food Technology 14:8-13. 1960.

Experimentally varying the processing conditions of precooked freeze-dried hams failed to increase storage stability beyond that of commercially cured hams. Stability of the stored samples is affected by a high moisture level. Vacuum canning is superior to nitrogen or carbon dioxide prepackaging; while stabilizers have no effect. Water absorption capacity on rehydration varies in the muscles, affecting acceptability.

10. BABBIT, J. D.
Hysteresis in the adsorption of water vapour by wheat. Nature 156:265-266. 1945.

That hysteresis is present in the sorption of water vapor by wheat is shown by the adsorption desorption isotherms of No. 1 Garnet wheat at 24.5C.

11. _____
Observations on the adsorption of water vapor by wheat. Can. J. Research F27:55-72. 1949

The adsorption and desorption of water vapor by wheat was measured by means of a McBain sorption balance. Curves are obtained showing the rate at which moisture is adsorbed by kernels of wheat directly exposed to a humidified atmosphere, and a theory is advanced to account for the rate of adsorption. It is shown that the rate of adsorption is governed largely by the time taken for the moisture to diffuse up to the surface of the wheat. Under storage conditions, this is much greater than the time required for the moisture to penetrate the kernel of wheat from its surface.

12. _____
On the adsorption of water vapour by cellulose. Can. J. Research 20A:143-172. 1942.

...An attempt is made to gather together the best available data on the adsorption of water vapour by cellulose and to draw from this data a

unified picture of the phenomenom. ...Various theories explaining the adsorption isotherm are tested. ...Thus it is doubtful whether the adsorption is monomolecular or polymolecular. ...An analysis is made of the data available for calculation of the heats of adsorption, and the values obtained from the different sources are compared. ...Finally, an explanation is advanced to account for the experimental fact that there is a reduction in total volume when water vapour is adsorbed on cellulose. ...

13. BAILEY, GLEN F., DUTTON, HERBERT J., AMBROSE, ANTHONY M., WILSON, ROBERT H. AND DeEDS, FLOYD
The content and biological availability of carotene in dehydrated carrots stored at high temperatures. Arch. Biochem. Biophys. 10:125-130. 1946.

Dehydrated carrots stored at 98°F and 120°F in an atmosphere of CO_2 became unacceptable as food, but the carotene content was not lowered at 120°F as much as it was at 98°F.

14. BARRER, RICHARD M.
Diffusion in and through solids. 464p. Cambridge Univ. Press. 1952.

15. BARTON-WRIGHT, E. C.
Studies on the storage of wheaten flour. III. Changes in the flora and the fats and the influence of these changes on gluten character. Cereal Chem. 15:521-541. 1938.

Deterioration in stored flour with a moisture content of 16% or over is not due to bacteria, but to an increase in fungal flora. Deterioration of gluten quality is due to unsaturated fatty acids. In samples with a moisture content of 16% and over, the gluten improved in quality due to the removal of fats and fatty acids by fungi.

16. BEARDSLEY, C. L., PRINDLE, R. F. and STEVENS, H. P.
Retention of vitamins in dehydrated vegetables during storage. Proc. Inst. Food Technol. 208-225. 1943.

Analyses have been made on fourteen (14) dehydrated vegetables during six months of storage at 98°F. and 70°F. Results indicate that vacuum, nitrogen and carbon dioxide gas-packing procedures are equivalent, and preserve ascorbic acid and carotene to a greater degree than is possible in air-packed samples. Thiamine retention was not appreciably affected by packaging method but was greatly influenced by storage temperatures. Increase in storage temperature hastens the loss of ascorbic acid, probably by accelerating its reaction with oxygen. No consistent effects of temperature on the stability of carotene were noted.

17. BECKER, H. A. and SALLANS, H. R.
A study of the desorption isotherms of wheat at 25°C. and 50°C. Cereal Chem. 33(2):79-91. 1956.

Desorption isotherms for wheat have been determined at temperatures of 25°C. and 50°C. Differential net heats of desorption calculated from the isotherms indicate that the initial heat is in the order of 7-10 k. cal. per mole of water desorbed and that the differential heat becomes negligible in comparison with the normal heat of vaporization of water at moistures much greater than 30%, dry basis. Heats of dehydration have been computed and indicate that the total heat of dehydration is approximately 43-47 cal. per g. of wheat, dry-matter basis. Average values of the net heat of desorption to be used in drying calculations have been computed. It is also shown that there is an evolution of heat when a drying wheat kernel is allowed to shift from nonuniform to uniform moisture distribution at constant average moisture content, and the magnitude of this effect is evaluated.

18. _____ and SALLANS, H. R.
A theoretical study of the mechanism of moisture diffusion in wheat. Cereal Chem. 34(6):395-409. 1957

The properties of the coefficient for the diffusion of moisture out of wheat are directly related to the moisture desorption isotherm. A three-dimensional flow mechanism applies at moistures above the critical level (10 to 12% dry basis), while at moistures below this critical level the properties of the diffusion coefficient are best explained by a two-dimension mechanism. The three-dimensional mechanism is based on the equation for viscous flow through a porous medium, and the desorption equilibrium water vapor pressure gradient is used as the driving potential. The two-dimensional mechanism is based on the equation for flow of an adsorbed film, and employs the two-dimensional film pressure as the driving potential. The evidence presented indicates that the adsorbent molecules are the structural units of wheat which are involved in moisture sorption and that they control the rate of diffusion.

19. BENLLOCH, A. ESCARDINO and SIERRA, L. J. ROS
Dehydration of pre-cooked rice. I. Determination of equilibrium moisture. Rev. Agroquim. Tecnol. Alimentos 3:27-33, 1963.

Equilibrium moisture contents of pre-cooked rice prepared from the varieties Bluebonnet and Balilla were determined at R. H. up to 92.5% at 25°. The equilibrium curve varies with initial moisture content (hysteresis effect), but is little effected by air temp. (from 25 to 110°) at R. H. between 0 and 11%. (From J. Sci. Food Agric. 14(10):ii192)

20. BENSON, SIDNEY, W. and SRINIVASAN, R.
The effect of temperature on the sorption of polar gases by proteins. J. Am. Chem. Soc. 77:6371-6372, 1955.

It has been previously shown that the sorption of polar gases by solid proteins is accompanied by the formation of a protein-gas complex of extremely low vapor pressure at room temperature (i.e. $\sim 10^{-5}$mm.). It was proposed that the complex was a stoichiometric compound formed by acid-base interaction of the gas and protein substrate. Isotherms for the desorption of HCl from egg albumin were studied at 32° and at 52°C. The isotherm for 52°C clearly shows an isobaric region in the neighborhood of 0.1mm. which can be interpreted as evidence for compound formation. The presence of an isobar in the 32° desorption isotherm can be reasonably inferred.

21. BENSON, SIDNEY W. and ELLIS, DAVID A.
Surface areas of proteins. I. Surface areas and heats of adsorption. J. Am. Chem. Soc. 70:3563-3569, 1948.

Measurements of surface areas of crystalline proteins by the B.E.T. (Brunauer-Emmett-Teller) method, using dry nitrogen, showed qualitative agreement with observations of the large particles under the electron microscope. Area measurements obtained from water adsorption data of other workers are from 40-200 times larger than those obtained from nitrogen adsorption data, indicating that water and nitrogen adsorption are quite different phenomena. Calculation of partial molal heats of adsorption as a function of volume adsorbed may be made from both nitrogen and oxygen isotherms.

22. _____ and ELLIS, DAVID A.
Surface areas of proteins. II. Adsorption of non-polar gases. J. Am. Chem. Soc. 72:2095-2102, 1950.

Adsorption isotherms of a series of non-polar gases of different molecular dimensions on dry, lyophilized proteins were determined. These isotherms, treated by the B.E.T. (Brunauer-Emmett-Teller) theory, were used to calculate the surface areas of the proteins and the partial molal differential heats of adsorption for the different gases. Results indicate that the proteins have no fine pore structure.

23. _____, ELLIS, DAVID A. and ZWAMZIG, ROBERT W.
Surface areas of proteins. III. Adsorption of water. J. Am. Chem. Soc. 72:2102-2105, 1950.

Measurements of water adsorption by two different proteins show that it is independent of the surface area in the range below one-fourth

saturation pressure. It is thus inferred that water adsorption is quantitatively different from nitrogen adsorption. Studies on the rates of water adsorption indicate that in the absence of air the rates are immeasureably fast, the observed rate being the rate of heat loss to the bath.

24. BENSON, S. W. and RICHARDSON, R.L.
A study of hysteresis in the sorption of polar gases by native and denatured proteins. J. Am. Chem. Soc. 77:2585-2590. 1955.

A modified McBain sorption balance has been used to measure the sorption-desorption isotherms of various polar gases, on native and heat denatured proteins at 25 and 40°. The relative sorptive capacities of egg albumin and bovine plasma albumin follow the same trend in binding the following vapors: $H_2O > EtOH > Et_2O > EtCl$. Apparently the amount of sorption decreases as the adsorbate becomes more restricted in its ability to form hydrogen bonds with the solid protein adsorbent. The same trend was observed with heat denatured egg albumin. The series MeOH, EtOH, and i-C_4H_9OH on egg albumin at 25° showed a marked decrease in the amount of sorption with increasing size of the adsorbate molecule. All the isotherms showed hysteresis loops which could be approximately related to the total amount of sorption and the molar volume of the adsorbate. The hysteresis loops were quite reproducible, even after three successive cycles and sorption-desorption points showed negligible drift in 10-40 hour periods. The dissipation of free energy upon completion of a hysteresis loop was calculated with the aid of the Gibbs-Duhem equation. The values, expressed in kcal./mole protein, for egg albumin at 25° were: H_2O = 66; MeOH = 79 and EtCl = 38. Calculation of the heats of sorption and desorption by means of the Clausius-Clapeyron equation for EtOH in egg albumin showed quite normal behavior in contrast to the values reported on earlier for H_2O on bovine plasma albumin.

25. _____ and SEEHOF, JERROLD M.
The surface areas of proteins. VI. Vapor phase titrations with polar gases. J. Am. Chem. Soc. 75:3925-3928. 1953.

The irreversible sorption of HCl, BF_3, CH_3NH_2 and NH_3 on a series of representative proteins has been investigated with the intention of determining the chemical reactivity of the protein as a function of the aforementioned gases. Methods have been developed which distinguish between "free" basic and "free" amino groups and which show promise of being able to elucidate the internal structural features of many proteins and indeed of other large organic molecules. It has been found possible to titrate the free amino groups by two independent methods and the free basic groups by another, the agreement of the free amino groups with chemical analysis being marked. The whole procedure is carried out in a vacuum system and at no time do the proteins come into contact with

anything except the racting gas, water vapor and all solvents being excluded from the process. It is proposed that the irreversible sorption of polar gases is merely the end point of the more general hysteresis phenomenon and that hysteresis itself can be considered as being intimately tied up with the chemical groupings within a protein.

26. BERLIN, E. HOWARD, N. M. and PALLANSCH, M. J.
Specific surface areas of milk powders produced by different drying methods. J. Dairy Sci. 47(2):132-138. 1964.

Low-temperature (-195 C) adsorption of N_2 was used to study the physical surface features of whole and skimmilk powders produced by different drying techniques. Specific surface areas were calculated using the Brunauer-Emmett-Teller (BET) multilayer adsorption theory. All the milk powders exhibited rather low surface areas ($\sim$.1-.6m^2/g) and abnormally low values for the energy of adsorption of N_2. Comparison of these surface areas with those obtained by permeametry yielded information on the relative porosities of the various powders. Conventional spray-dried powders were less porous than the instantized powders and the spray-dried foams. In addition, the surface areas of several milk constituents, including lactose, α-lactalbumin, β-lactoglobulin, and Na-α-caseinate were measured.

27. BETTELHEIM, F. A., STERLING, C. and VOLLMAN, D. H.
Pectic-substances-water. I. Structural changes in the polygalacturonide chains during water adsorption. J. Polymer Sci. 22:303-314. 1956.

An apparatus suitable for studying adsorption of water vapor both volumetrically and gravimetrically is described. Water vapor isotherms of highly esterified pectin, sodium pectate and pectic acid were determined. Equatorial and meridional spacings of the x-ray diffraction patterns were measured as a function of equilibrium water content in these materials. The interchain separations, as measured by the changes in the equatorial spacings of x-ray reflections, follow the shape of the adsorption isotherms. In esterified pectin and sodium pectate, the fiber repeat period increases until 5 molecules of water content per 3 galacturonide residues are adsorbed, thereafter remaining constant. The fiber period of pectic acid is constant throughout water adsorption.

28. _____ and EHRLICH, SANFORD H.
Water vapor sorption of mucopolysaccharides. J. Phys. Chem. 67(10):1948-1953. 1963.

Water and deuterated water vapor sorption isotherms were obtained on calcium salts of chondroitin sulfates A, B, and C, as well as on heparin. The sorptive capacity and extent of hysteresis were analyzed and correlated with the thermodynamic functions of sorption and with the BET "monolayer". Calcium chondroitin sulfate C, on the

other hand, has almost free swelling properties with minimal hysteresis effect. The water sorptive and retention capacities were correlated with molecular structure.

29. BIENENSTOCK, B. and POWERS, H. E. C.
Introducing the "Equilibrium Relative Humidity" of a sugar.
Int. Sugar J. 53:254-255. 1951.

The hygro-equilibrium of a sugar is suggested as a useful measure of sugar quality and stability. Knowledge of the percentage of H_2O in the sugar at equilibrium at 75% relative humidity, will enable one to determine, by reference to a chart, the relative humidity of the atmosphere in equilibrium with it, here termed "Equilibrium Relative Humidity" (E.R.H.). The knowledge of E.R.H. will throw considerable light upon many problems associated with H_2O changes in sugar in store or transit. (C.A. 4510629c)

30. BLOCK, ABRAHAM, ELLISON, FRANK E. and HEWITT, ERIC J.
Study of the application of relative humidity and moisture vapor pressure measurements for the determination of the moisture content of dehydrated foods. Evans Research and Development Corp. Progress Reports. 15 February - 15 November 1963, Nos. 1&2 (combined), No.3. (Contract DA 19-129-AMC-55(N)).

The object of the project is to conduct a comparative study of the relative humidity and moisture vapor pressure methods for the determination of the moisture content of dehydrated foods. The reports compare the results of moisture content determinations carried out on precooked, freeze dried shrimp and chicken by the hygrometric, manometric and vacuum oven methods. Dehydration cabbage, non-fat milk, red bell peppers, potato and rice were also used.

31. BRADLEY, R. STEVENSON
Polymolecular adsorbed films. II. The general theory of the condensation of vapors on finely divided solids. J. Chem. Soc. 1799-1804. 1936.

The equation $\log (p_s / p) = K_1 K_3^{a} + K_4$, where p and p_s are the pressure and saturation pressure respectively, a is the weight adsorbed, and K_1, K_3, and K_4 are constants, has been deduced for the adsorption of dipolar vapors on finely divided solids. Agreement is obtained with published experimental data over a wide range of p/p_s, except at high pressures, when capillary condensation occurs. The formation of liquid meniscuses is discussed.

32. BRASTAD, W. A. and BORCHARDT, L. F.
Electric hygrometer of small dimensions. Rev. Sci. Instr. 24(12:1143-1144. 1953.

An electric hygrometer of the Dummore type has been constructed so reduced in size as to fit inside the end of a hypodermic needle. A special

indicating circuit is required because of the small current permissible across the hygroscopic film. Relative humidities associated with surfaces as small as 0.001 square inch have been measured.

33. BREESE, MICHAEL, H.
Hysteresis in the hygroscopic equilibria of rough rice at 25°C. Cereal Chem. 32:481-487. 1955.

Hysteresis in the hygroscopic equilibria of rough rice at 25°C. was measured at relative humidities from 10 to 90%. A difference greater than 1% between the adsorption and desorption equilibrium moisture contents was maintained over the range of relative humidities from 20 to 80%, but exceeded 1.5% only at relative humidities from 50 to 70%. Rough rice at moisture contents between 12.6 and 14.1% may be in equilibrium with a relative humidity of 75%.

34. BRIGGS, DAVID R.
Water relationships in colloids. II. "Bound" water in colloids. J. Phys. Chem. 36:367-386. 1932.

A theoretical basis for bound water determinations in colloid systems is outlined in terms of the relative vapor pressure-water content (vapor pressure isotherm) of the colloid. Bound water is defined as that portion of the water in a system containing colloid and crystalloid which is associated with the colloid together with those ions that form a part of the colloid complex. Bound water is not a fixed quantity of water associated with the colloid but varies with the activity of the water in the system in a manner consistent with the vapor-pressure isotherm of the colloid. At any activity of the water in a system in which colloids and crystalloids are in equilibrium, the amount of water associated with, or bound by, a given weight of any of the non-water components is always the same, provided the various non-water components have not reacted with each other. Some of the methods that have been used for the determination of bound water are interpreted in terms of this picture.

35. BROCKINGTON, S. F., DORIN, H. C. and HOWERTON, H. K.
Hygroscopic equilibria of whole kernel corn. Cereal Chem. 26:166-173. March 1949.

The relative humidities of air in equilibrium with shelled yellow corn conditioned to moisture contents between 9.4 and 22.6% were determined at 80° $\pm$ 0.2°F. with a new type of electric hygrometer. Moisture determinations were carried out with the Brown-Duvel apparatus as well as by a two-stage vacuum oven technique in which the second stage involved drying at 135°C. in a vacuum oven for five (5) hours. The critical moisture content of shelled, yellow corn for safe storage, namely that in equilibrium with a relative humidity of 75%, was found to be 13.8 $\pm$ 0.2% by the Brown-Duvel method and 14.7 $\pm$ 0.1% by the two-stage vacuum oven technique.

36. BROOKS, J.
Dried egg. III. The relation between water content and chemical changes during storage. J. Soc. Chem. Ind.62:137-139. 1943.

Changes in the amount of orthophosphate, acid-soluble phosphorous, and in the acidity of the ether extract were measured in samples of dried whole egg of different water contents stored at 15°, 25°, and 37°C. The rate of change depended on the water content. Below 4-5% water there was little change but above this level the rate increased with increasing water content. The relation of these results to commercial conditions of storage is discussed.

37. BRUNAUER, STEPHEN
The adsorption of gases and vapors. Vol.1, Physical adsorption. (London, Princeton Univ. Press.) 1943.

38. _____, EMMETT, P. H. and TELLER, EDWARD
Adsorption of gases in multimolecular layers. J. Am. Chem. Soc. 60:309-319. 1938.

A critical discussion of the polarization theory of multimolecular adsorption is presented. It is shown that the adsorption energy due to attraction of dipoles induced into a non-polar gas like argon is insufficient to constitute a major portion of the binding energy between adsorbed layers.

Derivation of adsorption isotherm equations for multimolecular adsorption are carried out on the assumption that the same forces that produce condensation are also responsible for multimolecular adsorption.

Numerous applications of the equations are given to experimental adsorption isotherms obtained by other investigators as well as by us.

39. BURR, HORACE K. and SILVEIRA, VERNON G.
Stabilization of dehydrated cabbage by in-package desiccation. Food Technol. 8:452-456. 1954.

Montmorillonite was tested as a possible substitute for calcium oxide as an in-package desiccant for dehydrated cabbage. While somewhat less efficient than lime, it permitted a substantial stabilization of the product at a sacrifice of only a few percent of container volume. A commercial two-way-stretch paper was found to have desirable permeability and mechanical properties for use as a desiccant container. It can be fabricated into bags and the bags filled on automatic heat-sealing equipment. A new rehydration test for dehydrated cabbage is described.

40. BURTON, W. G.
Mashed potato powder. III. The high-temperature browning of mashed potato powder. J. Soc. Chem. Ind. T64:215-218. 1945.

If mashed potato powder is stored at different temperatures two types of deterioration may be detected: (1) the development of a brown color and charred taste and (2) the development of an "off" flavor. Both are accelerated by increasing the storage temperature but at high temperatures the latter is masked by the former. Both are influenced by moisture content promoting the first and retarding the second. The first type of deterioration is the subject of the present paper.

41. _____
Mashed potato powder. IV. Deterioration changes due to oxidative changes. J. Soc. Chem. Ind. 68:149-151. 1949.

The development of an "off" flavor, as distinct from a charred taste, in mashed potato powder is probably due to the oxidative rancidity of the potato fat. It is accelerated by storage in the light, and also, though not to a marked extent, by increasing the storage temperature. Increasing the moisture content of the powder considerably retards this type of deterioration, as does storage in an atmosphere of nitrogen with less than 1% of oxygen. Ascorbic acid is lost during storage in air, the more rapidly the higher the moisture content and storage temperature. A mould taint may occur at moisture contents greater than 12%.

42. _____
The Potato. (London, Chapman and Hall), 319p. 1948.

43. _____
The storage life of a sample of potato flour produced from potato slices dried in a sugar beet factory. J. Soc. Chem. Ind. 64:85-86. 1945.

Deterioration of potato flour during storage takes the form of darkened color and loss of ability to absorb water. Mould growth may occur if the equilibrium relative humidity is as high as 75% (= 15% moisture content). Darkening in color can be correlated with a decrease in hexose sugars and amino-acids, and with changes in the buffer system. It is accelerated by increased moisture content and temperature.

44. BUSHUK, W. and WINKLER, C. A.
Sorption of water vapor by wheat flour, starch and gluten. Cereal Chem. 34:73-93, 1957.

Adsorption-desorption isotherms for water vapor on flour, starch, and freeze-dried and spray-dried gluten have been obtained at 27°C. using a McBain-Bakr sorption balance in conjunction with a high-vacuum technique. Characteristic sigmoid isotherms showing linear hysteresis were obtained in the relative pressure range to 0.85 for the four adsorbents. The hysteresis loops were quite reproducible and the sorption was completely reversible if the relative pressure of 0.9 was not exceeded. At higher relative pressures the flour and gluten were physically altered and the sorption was no longer reversible. At lower pressures, considerable caking was observed in flour and gluten, but not in starch. Apparently, this caking did not have any effect on subsequent adsorption on the sample. Adsorption of water vapor by flour appears to be a bulk property of the material and not dependent on particle size. A 24-hour heat treatment of the flour at 100°C. in a vacuum reduced its sorptive capacity for water vapor by about 20%. The effect of temperature on adsorption of water vapor was similar for flour, starch, and gluten; the effect was greatest at low adsorption (low relative pressures) and became almost negligible as the saturation pressure was approached. For low adsorptions, the isoteric heat of adsorption for the three materials was considerably higher than the heat of condensation but decreased gradually as the amount adsorbed increased, until at about 16% to 20% moisture content the isosteric heat was essentially equal to the heat of condensation. A reasonably good fit of the Brunauer, Emmett, and Teller (BET) equation was obtained for the flour-water isotherm if the number of adsorbed layers at saturation pressure was assumed to be five or six. The BET area was 235 sq. m/g and the BET heat of adsorption was 12.6 kcal./mole.

45. _____ and HLYNKA, I.
Weight and volume changes in wheat during sorption and desorption of moisture. Cereal Chem. 37:390-398. 1960.

The toluene-displacement pycnometric method was applied to measure the change in volume of whole wheat with gain or loss of moisture after equilibration at various relative pressures of water vapor. The corresponding weight changes were determined also. A plot of the volume changes against the equilibrium relative pressure gave a volume isotherm with hysteresis between the sorption and the desorption branches similar to that in the weight isotherm.

46. CARDEW, M. H. and ELEY, D. D.
The sorption of water by haemoglobin. In Fundamental aspects of the dehydration of foodstuffs. p.24-30 (London, Soc. Chem. Ind.) 1958.

The adsorption of water on freeze-dried haemoglobin (ox) and alcohol-denatured haemoglobin (ox) has been followed by the weighing

bottle and salt solution method. Even after seven months, a hysteresis loop was still apparent, and of the two branches, the adsorption branch gave the closest fit to the BET equation. The monolayer values corresponded to adsorption of water on about 73% of the polar side chains, probably spread out over the surface of the molecule, regarded as a prolate spheroid 45Å x 45Å x 65Å. Differential and integral heats and entropies have been calculated by an application of the methods of Hill et al to the adsorption branches of the isotherms. These results support the 'freezing' of water molecules on localized sites fairly well separated on the molecular surfaces, and there is a clear decrease of integral entropy to a minimum over the complete monolayer. The fact that this behavior is not observed in silk fibroin may be due to entropy contributions from the chain segments.

47. CARR, D. S. and HARRIS, B. L.
Solutions for maintaining constant relative humidity.
Ind. Eng. Chem. 41:2014-2015. 1949.

The aqueous tensions maintained by twelve saturated aqueous salt solutions in an enclosed space from room temperature to 90°C. are given and the relative humidities calculated therefrom. The salts include the halides of potassium and sodium, the nitrate, nitrite, chromate, and dichromate of sodium, and chromic oxide. The data were obtained by a static method using a modification of the isoteniscope of Smith and Menzies.

48. CARTER, EDWARD P. and YOUNG, GEORGE Y.
Effect of moisture content, temperature, and length of storage on the development of "sick" wheat in sealed containers.
Cereal Chem. 22:418-428. 1945.

"Sick" wheat, produced artificially by storing sound wheat of various moisture contents in sealed jars at various temperatures, developed with increasing moisture content, temperature and length of storage. The few jars developing visible fungus growth were discarded. Wheat containing 12.2% moisture stored at 40°C. develop "sick" wheat symptoms when stored 279 days or longer, but not when stored at a lower temperature. Wheat containing 18.6% moisture, stored at 5°C. for 32 days developed a small amount of "sick" wheat and 100% "sick" wheat at higher temperatures or longer periods. The development of the "sick" wheat condition in general was accompanied by loss in viability and increase in fat acidity.

49. CASSIE, A. B. D.
Multimolecular adsorption. Trans. Faraday Soc. 41:450-458. 1945.

Statistical formulas for multimolecular adsorption of a single species are derived based on the assumption that if A molecules of pure liquid are adsorbed by unit mass of solid, X are adsorbed at low-energy sites, and (A-X) are adsorbed at sites identical with those available to the molecules in the pure liquid. Interchange between the two forms give a free energy of mixing, and the distribution between the two forms is determined by the condition that the total free energy of the phase should be a minimum. Each contribution to the total free energy is calculated. When applied to localized sites, an equation is derived identical with that of Brunauer, Emmett, and Teller. When applied to a mobile monolayer, the latter must be gaseous to give an adsorption isotherm or to give surface adsorption that varies with the concentration of the solute in the solution. This isotherm is everywhere convex to the pressure axis as exemplified by H_2O vapor on charcoal. In this case heat is adsorbed when H_2O passes from liquid in bulk to the monolayer, the value per molecule being 2200 calories.

50. CHICHESTER, C. O.
Storage stability of freeze-dried peaches. Abstracts of Papers, Annual Meeting of the Institute of Food Technologists. Food Technol. 10(5, sup.) 22. 1956.

Comparison, over a period of 120 days, of the rate of deterioration of freeze-dried peaches and conventionally-dehydrated peaches at a storage temperature of 110°F. (From National Agric. Lib., Library List no.77, 1963.)

51. CHORBAJIAN, TORCOM
Moisture equilibria in seeds. Ph.D. thesis - Iowa State College. Dissertation Abstr. 19:403. 1958.

Adsorption and desorption isotherms were obtained at 20° and 30° under varying conditions. Thermodynamic functions of free energy, enthalpy and entropy are calculated. Heat of desorption was inversely related to the moisture content of the seed. The heat of desorption is negligible compared with heat of vaporization of water at moisture contents $>$ 15%. (From J. Sci. Food Agric. Abstr. 1959, i-248)

52. CHRISTIAN, JOHN HINTON BASSETT
Water activity and the growth of microorganisms. In Recent advances in food science - 3 (London, Butterworths) pp.248-255, edited by James Muil Leitch and Douglas N. Rhodes. 1963.

53. COLE, L. J. N.
The effect of storage at elevated temperature on some proteins of freeze-dried beef. J. Food Sci. 27(2):139-143. 1962.

Describes two series of experiments conducted at the Defense Research Medical Laboratories in Toronto. A moisture-free atmosphere was used in the studies. Primary interest was in determining whether two enzymes, each representing a different group of proteins, were affected equally by storage, and in studying the effect on the "solubility" of different components. (From Nat. Agric. Lib., Library list no. 77, 1963).

54. COLEMAN, D. A. and FELLOWS, H. C.
Hygroscopic moisture of cereal grains and flaxseed exposed to atmospheres of different relative humidity. Cereal Chem. 2:275-287. 1925.

Cereal grains are hygroscopic; thus weight changes in storage are due to variations in the moisture content under varying storage conditions. Experiments were carried out to ascertain the equilibrium moisture content of cereal grains and flaxseed at different relative humidities at 25° to 28°C. Hygroscopic moisture of samples of different cereal grains did not vary appreciably, while flaxseed contained less than the cereal grains studied. When in equilibrium, each increment of increase in humidity is accompanied by an acceleration in the rate of increase in content of hygroscopic moisture.

55. CONNELL, J. J.
The effect of drying and storage in the dried state on some properties of the proteins of food. In Fundamental aspects of the dehydration of foodstuffs. p.167-177 (London, Soc. Chem. Ind.) 1958.

Reviews many studies attempting to explore reactions underlying textural deterioration in foods. Among foodstuffs investigated here was freeze-dried fish. It is believed that the freeze-drying process may be the gentlest way of drying proteins. However, it was reported that the texture of dehydrated fish (vacuum-dried or freeze-dried) becomes drier and tougher quickly after only moderate storage. (From Nat. Agric. Lib. Library list no. 77, 1963.)

56. _____
Some aspects of the texture of dehydrated fish. J. Sci. Food Agr. 8:526-537. 1957.

The two principal factors (micro-structure of fibres and fibre substance) influencing the texture of dehydrated fish are examined in a number of different products. A highly porous micro-structure seems to be necessary both for good texture and good reconstitution properties. The importance of cross-links between the protein peptide

chains in relation to texture is emphasized and evidence presented that hydrogen and disulphide cross-links do occur in dehydrated fish.

57. CONTINENTAL CAN COMPANY RESEARCH LABORATORIES, CHICAGO, ILL. New facts about packaging and storing dehydrated foods. I - XI. Food Inds.16:171-175, 267-269, 326, 366-370, 417-418, 458-461, 504, 542-545, 635-637, 680-681, 702-704, 748, 815-817, 865, 903-905, 955, 991-993, 1046. 1944.

Studies were made on 10 dehydrated foods to determine the effect of packaging, storage time, storage temperatures, and in some cases moisture contents lower than specified on the keeping and eating quality and vitamin content of the selected fruits and vegetables. Under proper conditions of packaging and storage, acceptable foods can be prepared after 12 months storage.

58. COONEY, PATRICIA M., EVANS, C. D., SCHWAB, A. W. and COWAN, J. C. Influence of heat on oxidative stability and on effectiveness of metal-inactivating agents in vegetable oils. J. Am. Oil Chem. Soc. 35(4):152-156, 1958.

Metal-inactivating agents, such as citric acid, sorbitol, lecithin, and carboxy-methylmercapto succinic acid, are not active in unheated vegetable oils. Apparently trace metals present in normal glyceride oils are held within a complex of unknown structure. After heating an oil, the metals can be complexed by metal-inactivating agents, such as citric acid. The release of metals appears to be associated closely with the breakdown of the fatty acid hydroperoxides. Formation of some association or complex between the metal and the hydroperoxide group or between the metal and the unsaturated linkage of the fatty hydroperoxide is suggested. The metals are held very tenaciously within this unknown structure. Although the metal is not available as an uncomplexed metallic ion, it does behave as a very strong pro-oxidant catalyst. The application of heat releases the metal so it can be complexed by added metal inactivators.

59. COULTER, S. T., JENNESS, ROBERT and GEDDES, W. F. Physical and chemical aspects of the production, storage and utility of dry milk products. Advances in Food Research 3:45-118. 1951.

An attempt has been made to assemble and to integrate the available information on physical and chemical aspects of the manufacture and storage of the principal dry milk products, with special emphasis on dry whole milk for beverage purposes.

60. CRANE, JOHN C., STEELE, HAROLD K. and REDFERN, SUTTON
Techniques for estimating the stability of food products: Active dry yeast. Food Technol. 6:220-224. 1952.

Various techniques used in establishing the life expectancy of active dry yeast are described. These techniques include functional tests on both packaging materials and on the product. It is first necessary to determine the factors which affect the product. Knowing these factors, one selects packaging materials which will give adequate protection.

61. CRANK, J.
The mathematics of diffusion. Oxford, Clarendon Press, 347p. 1956.

62. CUENDET, L. S., LARSON, ELOF, NORRIS, C. G. and GEDDES, W. F.
The influence of moisture content and other factors on the stability of wheat flours at 37.8°C. Cereal Chem. 31(5):362-389. 1954.

The stability of various grades of white and whole wheat flour from a hard wheat mix stored in sealed containers at 3, 6, 10, and 14% moisture and 37.8°C. decreased with decreasing refinement, with treatment with chlorine dioxide, and with an increase in the moisture content.

During 38 weeks storage at 3 and 6% moisture the baking quality of unbleached short patent flour showed little change; at 10 and 14% moisture the loaf volume decreased sharply after 38 and 10 weeks storage respectively. In contrast, whole wheat flour stored at 10 and 14% moisture lost in loaf volume after 26 and 3 weeks storage respectively. Heat treatment of the feed streams entering into whole wheat flour, treatment with 0.01% of two antioxidants, or storage under nitrogen did not retard the losses in breadmaking value upon storage at 14% moisture.

Development of objectionable odors was enhanced when the storage moisture was increased from 6 to 10 to 14%. Several samples stored at 3% moisture have more objectionable odors than those at 6%. Bleaching shortened the storage time at which undesirable odors were detected. Feed products acquired rancid odors more rapidly than flours.

Development of free fatty acids increased with decreasing refinement and was not influenced by bleaching. At 3% moisture, there was essentially no increase in fat acidity of the various flours whereas

at 14% moisture high percentages of the total lipids were hydrolyzed. Significant negative correlations were obtained between loaf volume and fat acidity but exchanging the lipids of sound and deteriorated flour indicated that other biochemical changes also contributed to the losses in baking quality. Peroxide and monocarbonyl values for the flour lipids were low and showed little change during the storage trials.

Sulfhydryl contents of the flours increased with decreasing refinement but were not significantly influenced by treatment with chlorine dioxide. The sulfhydryl values decreased in the flours stored at 6, 10 and 14% moisture.

Thiamine losses occurred in whole wheat flour after 3 weeks storage at 14% moisture. The red dog and wheat germ streams lost about 80% of their thiamine when stored for 52 weeks at 14% moisture.

The stability of bread flours may be enhanced by increasing the degree of refinement, eliminating treatment with oxidizing improvers, and decreasing the moisture content below normal commercial levels.

63. CULPEPPER, CHARLES W., CALDWELL, JOSEPH S. and WRIGHT, R. C. Effect of temperature and atmospheric humidity upon the behavior of dehydrated white potatoes in storage. The Canner 104(14):14, 16, 18-20:(15):15-16, 18, 26, (16):16, 18, 20, 22, 24, 30, (17): 27-28, 30, 32. 1947.

Calls attention to color changes in stored dehydrated potatoes which act as satisfactory indicators of the rate and amount of deterioration. At a given R.H., discoloration at 110°F was 3-4 times as rapid as at 90°, 25-35 times at 70°, and 70-80 times as rapid as at 50°F. At 110° and 90°F in a saturated atmosphere, discoloration was 16-20 times as rapid as in a dry atmosphere. At 50% R.H., the rate was 3-4 times that in a dry atmosphere. Deterioration of dehydrated potatoes at 110°F was sufficiently like that occurring at normal storage temperatures to make this temperature a satisfactory one for an accelerated storage test. Dehydrated potatoes with a high sugar content deteriorated rapidly. Treatment of potatoes with sulfur dioxide prior to drying was most effective in preventing deterioration at 70°F or lower when moisture content was below 10%, but this treatment was not very effective on dehydrated potatoes stored at high temperatures and at very high humidities.

64. DANEHY, J. P. and PIGMAN, W. W.
Reactions between sugars and nitrogenous compounds and their relationship to certain food problems. Advances in Food Research 3:241-290. 1951.

Work on the reaction between sugars and nitrogenous compounds is critically reviewed.

65. DAVIS, S. and McLAREN, A. D.
Free energy, heat and entropy changes accompanying the sorption of water vapor by proteins. J. Polymer Sci. 3(1):16-21. 1948.

Recently published measurements of moisture sorption vs. relative humidity for a series of proteins have previously been analyzed in a way which permits calculation of the integral free energy of sorption for any final pressure of water vapor. The present paper is an extension of these calculations to additional proteins from the list reported by Bull; integral and differential free energies and integral and differential heats and entropies of sorption have been calculated as functions of the amounts of water sorbed on silk, wool, egg albumin (unlyophilized and heat coagulated), salmine, collagen, gelatin and lactoglobulin (crystalline and lyophilized). All calculations are referred to saturated water vapor as the standard state. Some of the proteins show positive net differential entropies of sorption at low vapor pressures. It is postulated that the partial molal entropy of sorption is made up of two terms, a negative entropy of sorption proper and a positive entropy of solution. Partial rearrangements of the protein chains at the beginning of the sorption process would effectively be an incipient solution which would give rise to a positive partial molal entropy of sorption if the second term is greater than the first. This speculation has support in the fact that the differential entropy of salmine, which dissolves at a relative vapor pressure of about 0.7, begins to show positive values at a relative vapor pressure of 0.35.

66. DESPAUL, JOHN E. and EZERSKI, DONALD W.
Rapid method for determination of moisture in freeze-dehydrated shrimp. J. Assoc. Off. Agr. Chemists 46(6):1001-1003. 1963.

Difficulties in determining moisture in freeze-dehydrated shrimp by toluene distillation method were overcome by drying several whole shrimp directly in a vacuum oven. This procedure is faster and more reliable than several other methods tried, and results of a limited collaborative study show that it compares well with the toluene distillation method.

67. DITTMAR, JOHN H.
Hygroscopicity of sugars and sugar mixtures. Ind. Eng. Chem. 27:333-335. 1935.

A definite relationship between the sucrose, invert sugar, and water content of various sugars and the relative humidity of the surrounding atmosphere has been found, and the equilibrium points have been graphed. The equilibrium relative humidity or vapor pressure of pure sucrose, dextrose, fructose, invert sugar, or sucrose-invert sugar mixtures with varying percentages of water can be determined directly from the graph.

68. DOLE, MALCOLM and McLAREN, A. D.
The free energy, heat and entropy of sorption of water vapor by proteins and high polymers. J. Am. Chem. Soc. 69:651-657. 1947.

Equations were derived for calculating the free energy and heat of sorption of water vapor by proteins. Comparison of data of Bull on water sorbed by proteins and nylon and recalculation by these equations were made. Calculations using the BET (Brunauer-Emmett-Teller) theory were also compared. Differential and integral free energies and heats of hydration for five polymers are graphed or tabulated.

69. DOTY, D. M., BERGDOLL, W. S., GREENE, L., LEWIS, W. R. and ELLIS, N. K.
Discoloration of white potatoes during dehydration. Indiana Agric. Exp. Sta., Lafayette, Final Report (Contract W44-109-QM-1013) 28p., 31 December 1947.

Studies were made on four varieties of white potatoes of the brown discoloration that occurs during dehydration and storage. The results indicate that the brown pigments are formed by condensation reactions between carbohydrate material and amino compounds. There is no direct correlation between sugar content and the tendency to brown.

70. DOTY, D. M.
Increasing product storage life -- Basic deteriorative reactions. In Freeze-drying of Foods; proceedings of a conference. Fisher, F. R. ed. Washington, National Research Council. p. 228-231. 1961.

Summarizes data produced in oxidative and non-oxidative reactions.

Points out basic importance here of temperature, moisture level, and packaging conditions. (From Nat. Agric. Lib., Library list no. 77, 1963)

71. DRAUDT, H. N., DAMON, C. E., HUANG, I. Y. and ROWE, C. Enzyme activity in freeze dried foods. Purdue University Progress Report No. 3, 6 p. (Contract DA 19-129-QM-1503), 19 May 1960-19 August 1960.

Observations are given for experiments underway on the oxygen uptake and on the survival of lipase activity in freeze dried beef stored at various moisture levels. Observations on the survival of peroxidase activity in unblanched peas stored at different moisture levels was given.

Surviving polyphenol oxidase, amylase and sucrase activity, as well as reducing sugar and free amino group content, was followed in freeze dried bananas held at different moisture levels.

72. DRAZGA, F. H., ESKEW, R. K. and TALLEY, F. B. Storage properties of potato flakelets. Food Technol. 18(8):91-94(2101-1204), 1964.

Experience has shown that potato flakes of about 6% moisture, packed in air and containing 50 ppm BHA plus BHT as antioxidant and 200 ppm sulfite, keep well at room temperature for approximately 6 months.

73. DUCK, W. N., CROSS, R. P., QUINN, L. P. and RINCON, J. A. PMCA research reveals reliable method for moisture determination in hard candy. Confectioners J. 81(971):32-34, December 1955.

Boiling point values for sugar solutions were determined which check well with actual values determined by other workers. Extrapolation from Spengler's boiling point data into the hard candy range of concentration leads to serious errors. The Bureau of Standards empirical equation does not describe the boiling point curve above 90% sugar.

Close agreement between the two methods, Karl Fisher vs. direct weight, used to obtain the moisture content of the boiling sugar solutions, indicates that the Karl Fisher method is a reliable method for moisture determination in hard candy. (Excerpt from Summary)

74. DUCK, WILLIAM and CROSS, ROBERT P.
Vapor pressure study of hard candy. Joint Technical Session of The National Confectioners' Association and American Association of Candy Technologists, Chicago, Illinois. 10p. 10 June 1957.

The vapor pressure of hard candy has a transition point at a temperature above which there is a true vapor pressure equilibrium relationship. Below this point there is no true equilibrium. The transition point is lowered by increasing moisture. Stickiness and graining appear to take place after hard candy is exposed to such a relative humidity which will raise the moisture content and lower the transition point to the temperature of the candy. The vapor pressure transition point appears to be the same as the transition point reported for specific heats of dextrose glass as well as viscosity, elasticity measurements, coefficient of expansion with glasses of other materials. Dextrine glasses show higher transition points than sugar glasses.

75. DUCKWORTH, RONALD BARRETT and SMITH, GRAHAM MacDONALD
Diffusion of solutes at low moisture levels. In Recent advances in food science -3, edited by James Muil Leitch and Douglas N. Rhodes. (London, Butterworths) pp.230-238, 1963.

76. DUNFORD, H. B. and MORRISON, JOHN L.
The adsorption of water vapor by proteins. Can. J. of Chem. 32:558-560, 1954.

Liang's method was used to correlate the results of the water sorption process by proteins at relative vapor pressures above 0.5 using Bull's data by the B.E.T. (Brunauer-Emmett-Teller) equation and by the Harkins - Jura equation.

The results indicate that the complete isotherm represents the formation of a film of at least two molecules thickness, the upper layer being condensed and occupying the same surface area as the underlying monomolecular layer.

77. DUNFORD, H. BRIAN and MORRISON, JOHN L.
The heat of wetting of silk fibroin by water. Can. J. of Chem. 33:904-912. 1955.

The heats of wetting by water of silk fibroin initially containing various amounts of adsorbed and desorbed water have been measured. These measurements along with the water vapor adsorption isotherm of Hutton and Gartside have been used to calculate the integral and differential heats, free energies, and entropies of adsorption.

78. EDWARDS, B. G. and DUTTON, H. J.
Role of phospholipides and aldehydes in discoloration. Ind. and Eng. Chem. 37:1121-1122, 1945.

A brown material from dehydrated whole egg powder, found in both the total ether extract and the cephalin fraction, has been concentrated. Evidence indicates that this material arises from the reaction of a cephalin amino group with aldehydes.

79. EHRLICH, SANFORD H. and BETTELHEIM, FREDERICK A.
Infrared spectroscopy of the water vapor sorption process of mucopolysaccharides. J. Phys. Chem. 67(10):1954-1960, 1963.

Infrared spectra of isomeric chondroitin sulfates and heparin were obtained during the different stages of the water and deuterated water sorption process. On the basis of the change in the integrated intensities of the different absorption bands, the role of the different polar groups in the water sorption process was investigated. The deuterium exchange was interpreted on the basis of accessibility of the hydroxyl groups toward water vapor at different vapor pressures. It was found that the different polar groups of the polymers bind water vapor simultaneously according to their steric accessibilities.

80. ELEY, DANIEL DOUGLAS and LESLIE, ROBERT BRUCE.
Hydration of solid proteins, with special reference to haemoglobin. In Recent advances in food science -3, edited by James Muil Leitch and Douglas N. Rhodes, (London, Butterworths) pp.215-217. 1963.

81. FELSHER, A. R., KOCH, R. B. and LARSEN, R. A.
The storage stability of vacuum-packed active dry yeast. Cereal Chem. 32:117-124, 1955.

Granular and pelleted active dry yeast packed in vacuum were stored at -20, 0, 40, 90, and 120 degrees F. (respectively, -29, -17.7, 4.4, 21.0, 32.1, and 49 degrees C.), and a weekly cycle of -20°F. (-29.0°C), and 40°F. (4.4°C.).

As the temperature of storage decreased, the shelf life of the active dry yeast improved. Freezing temperatures had no effect on the baking quality of active dry yeast nor did alternate periods of freezing and thawing temperatures of -20°F. (-29.0°C.) and 40°F. (4.4°C.). When active dry yeast is stored at 40°F. (4.4°C.) or lower it is usable for 21 months; at 90°F. (32.1°C.) the yeast was usable for 6 months;

and at 12°F. (49.0°C.) the life was 8 days. No significant difference was found between the storage stability of active dry yeast in pellet form and of that in granular form.

82. FINE, M. S. and OLSEN, A. G.
Tallowiness or rancidity in grain products. Ind. Eng. Chem. 20(6):652-654, 1928.

The development of tallowy odors in grain products can be delayed for long periods of time by appropriate control of the moisture content. In samples having moisture contents of 2 percent or less, tallowy odors developed relatively quickly. Moisture contents of approximately 5 percent were found to be protective. This protective effect became more pronounced as the moisture content increased. Samples of 10 to 12 percent moisture after about three years' storage are still free from any apparent tendency toward tallowiness. Suitable addition of moisture can also exert a "curative" effect in samples of initially low moisture which have developed tallowiness. Glycerol in concentrations of 0.25 to 0.5 percent also was found to postpone for long periods the development of tallowiness.

83. FISH, B. P.
Diffusion and thermodynamics of water in potato starch gel. In Fundamental aspects of dehydration of foodstuffs. Soc. Chem. Ind., London. (New York, Macmillan) p.143-157, 1958.

The dehydration process is described in terms of a diffusion coefficient which depends on the moisture content of the material. This coefficient varies over about three orders of magnitude in the range between dryness and saturation. Changes in the thermodynamic properties of water in starch gel occur as the moisture content is reduced, especially below 10% on the dry basis. The conclusion is that the slow transport of water in dry starchy material is associated with the loss of rotational freedom of the water molecules. The height of the energy barrier for the fundamental process of diffusion appears to increase as the moisture content of the material is reduced. Some practical remarks on the dehydration of gelatinous material are included.

84. FRASER, C. W. and HALEY, W. L.
Factors that influence the rate of absorption of water by wheat. Cereal Chem. 9:45-49, 1932.

Variety, time, temperature, and size of kernel are all factors which affect the amount and rate of absorption of water by wheat when immersed in water. Absorption is increased when the outer bran coat is broken by the process of scouring. Percentage of protein has very little effect on water absorption.

85. FREY, HAROLD J. and MOORE, WALTER J.
Adsorption of vapors on organic crystals. I. Adsorption of water vapor on glycine, leucine, diketopiperazine and diglycylglycine. J. Am. Chem. Soc. 70:3644-3649, 1948.

Adsorption of water vapor on powdered crystalline samples of glycine, leucine and diketopiperazine, of known inert gas surface area, was investigated at 15, 25, and 40°. The water adsorption appeared to occur primarily on the ionic COO- and NH_3+ groups of the amino acids and on the peptide linkage in diketopiperazine. Thermodyamic treatment of the adsorption isotherms indicates that the free energy of adsorption at the monolayer point is about 1000 calories less than the free energy of condensation of water vapor to liquid water. Diglycylglycine sorbed water to a much greater extent than the other crystals and appears to provide an intermediate case between surface adsorption and the extensive sorption observed with proteins.

86. FRIEDMAN, LEO and KLINE, O. L.
The amino acid-sugar reaction. J. Biol. Chem. 184:599-606, 1950.

Ten amino-acids were subjected to different conditions with and without glucose. The results of measurements on these show that the amino-acid sugar reaction is characterized by reduced microbiological availability of the amino-acids, browning, production of fluorescent compounds and characteristic ultraviolet absorption at 285m .

87. GANE, R.
Dried egg. VI. The water relations of dried egg. J. Soc. Chem. Ind. 62:185-187, 1943.

The water relations of dried whole egg have been determined at temperatures of 10°, 37°, 60°, and 80°C. over the range of humidity 0.05-0.70. From these data it is possible to estimate the water content of dried egg in equilibrium with humidities at any temperature likely to be encountered in normal commercial storage. The data also relate water content to the temperature and humidity of the air in commercial drying plants. Denaturation of the proteins, by heating prior to drying, has only a slight effect on the water relations of the dry product. The method of drying (spray-drying, or drying in the frozen state) does not seriously alter the water relations. The behavior of dried whole egg is directly proportional to, and can be calculated from, the relative amounts of white and yolk present in the mixture.

88. GANE, R.
Dried meat. III. The water relations of air-dried, pre-cooked beef and pork. J. Soc. Chem. Ind. 62:139-140, 1943.

The water contents of air-dried pre-cooked beef and pork vary with temperature in a normal manner up to a relative humidity of 0.4, but at higher humidities the water contents are approximately the same at the different temperatures studied (0-60°C.).

89. GANE, R.
The water content of wheats as a function of temperature and humidity. J. Soc. Chem. Ind. 60T:44-46. 1941.

The water relations of three varieties of commercial wheat have been examined. At 10° there was practically no difference in the water contents of whole grains and of kibbled wheat, when in equilibrium with air of a given relative humidity. Differences between water contents of the three kinds of wheat, under given conditions of temperature and relative humidity, were very small. Equilibration proceeds more rapidly at higher temperatures. At 0°, with whole grains the process may take from 70 to 80 days.

90. _____
The water relations of some dried fruits, vegetables and plant products. J. Sci. Food Agr. 1:42-46. 1950.

The water contents of some dehydrated plant products have been determined in atmospheres of known humidity within the range 0% to 80% saturation, usually at a temperature of 50°F. (10°C.) and also at 98.6°F. (37°C.), 140°F. (60°C.) and 176°F. (80°C.) with dried potato and dried carrot.

The non-diffusible colloids and soluble constituents each play a definite part in affecting the water content at any humidity; the colloids have a relatively high water content at low humidities and the soluble constituents have a low water content.

The humidity/water relations of mechanical mixtures, such as soup powders, can be calculated from the proportions and properties of the constituents.

91. GOLD, HARVEY J.
General application of near-infrared moisture analysis to fruit and vegetable materials. Food Technol. 18(4):586-587. 1964.

A near-infrared method for determining moisture gave good correlation with a vacuum-oven method over a range from about 2% to about 99% moisture. The types of materials tested ranged from dry powders to liquids.

92. GOODING, E. G. B. and DUCKWORTH, R. B.
An accelerated storage test for dehydrated vegetables. J. Sci. Food Agr. 8:498-504. 1957.

When dehydrated vegetables are stored at high temperatures (e.g. in the tropics) they eventually become unacceptable, in most

cases because of the development of brown pigments. Testing for 'tropical' storage life is usually carried out at 37°, but preliminary tests on a number of different dehydrated vegetables suggested that the deterioration of culinary qualities (color, flavor and texture) occurring in a certain number of days at 55° was approximately the same as that occurring in the same number of months at 37°. Further experiments on dehydrated potato have confirmed that there is a close correlation between the extent of browning developed under these two sets of conditions.

93. GOODING, E. G. B. and DUCKWORTH, R. B.
Accelerated storage tests for dehydrated vegetables.
Nature 177:897-898. 1956.

Tests on dehydrated vegetables stored at 37°, 55° and 70°C showed that the rate of browning at 55°C was approximately thirty times that at 37°C. A visual method of scoring the browning in dehydrated potatoes supports this finding.

94. _____ and TUCKER, C. G.
Dehydration of carrot. Food Manuf. 30:447-450, 460. 1955.

Carrots do not normally form a large portion of the British diet, but there has been some demand for dehydrated carrot for use by the Services, partly on account of the particularly high provitamin A (beta-carotene) content and partly in order to provide variety in the diet: in addition there is a small civilian market. In the past two years investigations at Aberdeen have ranged widely over problems of carrot dehydration, and have included efforts to improve the flavor of the dehydrated product and to produce it in forms other than strips or small dice; a study has been made of ways of reducing losses during processing, and of the possibility of increasing the tropical storage life of the product. These investigations are still at an early stage, but in this article an attempt is made to summarize progress so far.

95. _____, DUCKWORTH, R. B. and HARRIES, J. M.
The effect of post-harvest storage conditions of raw potatoes on the storage life (at tropical temperatures) of their dehydrated products. J. Sci. Food Agr. 7:444-456. 1956.

The increase in reducing sugar content of potatoes stored in a field clamp after a spell of cold winter weather was sufficient to halve the storage life of the dehydrated product when held at 98.6°F.

Conditioning of the potatoes after this cold spell for 2-3 weeks at 60°F immediately before dehydration lowered the reducing sugar content and led to some improvement in the product. The lowest reducing sugar contents and the products most resistant to deterioration during high temperature storage were obtained by keeping the raw potatoes, treated with a sprout depressant, in a shed with a minimum temperature of 43°F.

96. GOODING, E. G. B.
The storage behaviour of dehydrated foods. In Recent advances in food science. vol. 2, p. 22-40, John Hawthorn and Jas. Muil Leitch, (Butterworths, London) 1962.

Summarizes the data that have been gained to date with regard to oxidative and nonoxidative deterioration, and enzymic changes. A consideration of moisture, sugar, and sulphur dioxide content, and of methods of scalding is included. Some mention is made of techniques used for storage tests. Reference to freeze-dried foods is made throughout the discussion. (From Nat. Agric. Lib., Library list no. 77, 1963).

97. GORE, H. C. and RUTLEDGE, L. F.
Control of the darkening of dehydrated potato. Chem. Age 29:457-458. 1921.

Upon keeping at ordinary temperature the pale amber-colored dehydrated potato (sliced or riced) usually darkens, often becoming quite brown in a few months. No visible forms of microörganisms were found in such potatoes. Experimental work wherein 2 and 12 minute cooking periods were used in the preparation of the dehydrated potatoes showed that no darkening occurred in those kept at 35°F for 700 days and that time of cooking had no influence on rate of browning. The H_2O content at and below which darkening at room temperature is so slow as to be of no practical importance lies between 6.27 and 6.62% for sliced and 4.78 and 7.23% for riced potatoes. Browning was far more rapid at incubator temperature of 100-105°F than at room temperature averaging 75°F. (CA 16:1283)

98. _____ and MANGELS, C. E.
The relation of moisture content to the deterioration of raw-dried vegetables upon common storage. J. Ind. Eng. Chem. 13:523-524. 1921.

Unless raw-dried vegetables are dried to below certain moisture contents they will not retain their original color and flavor during storage at ordinary temperatures. The initial moisture contents at and below which the distinctive color and flavor are well retained for 6 months or more are as follows: carrots, 4.99 to 7.39%; turnips, 5%; onions, 5.74 to 6.64%; spinach, 3.81 to 5.38%; cabbage 3.00 to 3.34%.

99. GÖRLING, PAUL
Investigations into the behavior of vegetable substances during drying. (Untersuchungen zur Aufklärung des Trocknungsverhaltens pflanzlicher Stoffe.) Beilage zu Forschung auf dem Gebiete des Ingenieurwesens. Ausgabe B Band 22. Translated by Weigend. VDI - Forschungsh. 458, 1956.

The physical behavior of vegetable substances during dehydration is regulated by the sorption and shrinking properties during the moisture movement. The theories of this behavior and the equations for calculating it are given.

100. GT. BRIT. FOOD INVESTIGATION BOARD.
Report. London, 1955. 72p. 1954.

Brief review of current investigations of freeze-drying at Aberdeen Experimental Factory; observations on freeze-drying of cod, with regard to moisture content and browning; and reference to studies centering on protein change and reconstitution of freeze-dried fish. (From Nat. Agric. Lib., Library list no. 77, 1963)

101. GT. BRIT. FOOD INVESTIGATION BOARD.
Report. London, 1958, 81p. 1957.

Work with freeze-dried cod steaks and cod fillets is reviewed. Emphasis here centers on rate of heat transfer during processing, and changes in texture, taste, tenderness, and color during storage. (From Nat. Agric. Lib., Library list no. 77, 1963)

102. GT. BRIT. MINISTRY OF AGRICULTURE, FISHERIES AND FOOD.
The accelerated freeze-drying (AFD) method of food preservation. London, 1961, 169p. 1961.

103. GROVER, D. W.
The keeping properties of confectionery as influenced by its water vapour pressure. J. Soc. Chem. Ind. (London) 66:201-205. 1947.

The moisture vapour pressure of a foodstuff, regarded in relation to that of the surrounding atmosphere decides whether the loss or gain of moisture can occur and, to a considerable extent, whether the foodstuff can form an acceptable medium for micro-organisms. It follows that this property has great importance with regard to storage life. The moisture vapour pressure of confectionery has been studied firstly by measuring the vapour pressure/moisture-content relations of

the principal ingredients, namely sucrose, confectioners' glucose and invert sugar, and of some minor ingredients. The resulting information can be combined in the form of a number of formulae by means of which the moisture vapour pressure of most kinds of confectionery may be calculated from the composition. The figures so obtained agree well with direct measurements made on the individual samples. A wide variation in vapour pressure is observed between different classes of confectionery, these differences resulting in widely different keeping properties and requirements for satisfactory storage.

104. GUILBOT, A.
Application de la cryodessiccation aux aliments. (Application of freeze-drying to foodstuffs.) Aliment. et la Vie 45(10/12), 243-254. 1957.

Survey of studies reflecting development to date include: Basic introductory data, historical background, technical aspects (including freezing, drying, and heat transfer techniques, and equipment), main results obtained in laboratory or semi-industrial plants (regarding meat, fish, seafood, eggs, milk, bread, vegetables, fruit juice and beverages, characteristics of products, storage stability, application of process to various food industries (fish, eggs, milk, bread, vegetables, fruit, fruit juice, and beverages), nutritional information, and general outlook. (From Nat. Agric. Lib., Library list no. 77, 1963).

105. HALTON, P. and FISHER, E. A.
Studies on the storage of wheaten flour: II. The absorption of oxygen by flour when stored under various conditions. Cereal Chem. 14:267-292. 1937.

Earlier work on auto-oxidation is reviewed. The account of experimental work on the factors underlying the natural ageing of flour is divided into three parts: (1) experiments in which the flours were stored in an atmosphere of air at 25°C and the oxygen absorption was measured from day to day, (2) experiments in which flours were stored in an atmosphere of oxygen at 25°C and 60°C. The oxygen absorption was measured and the effects of storage were investigated by analytic means, and (3) experiments in which large samples were stored in air in tins and examined at regular intervals both by baking tests and by analytical methods. The results indicated that when flour is stored in air considerable absorption of oxygen occurs due to: (1) mite and similar small animals which breathe in oxygen (this factor can be suppressed by raising the flour to 60° or reducing the moisture content to below 12%, or by chloroform), (2) bacteria and fungi

which became active when the moisture content exceeds 12%, and (3) true chemical oxidation, which becomes more rapid as the moisture content is reduced. The oxidation of the fatty constituents appears to occur only when the flour is stored in oxygen. The difference in behavior as regards autoxidation of fat when stored in air and in oxygen is difficult to explain.

106. HAMM, REINER.
The water imbibing power of foods. In Recent advances in food science -3, edited by James Muil Leitch and Douglas N. Rhodes, (London, Butterworths) pp.218-229, 1963.

107. HANOUSEK, J.
Guarantee terms for packaged hygroscopic substances. Průmysl Potravin 12:255-260. 1961.

Influence of temperature and R.H. on the conservation of hygroscopic products, especially those of the food line, is examined. Storage and guarantee terms can be calculated in advance with consideration of the starting and admissible final content of water, sorption isotherms of the product, climatic conditions and permeability of the wrapping material for water vapour. A method for establishment of guarantee terms for hygroscopic products illustrated by experimental and calculation examples is suggested. (From J. Sci. Food Agric. ii-131, 1961) .

108. HARKINS, WILLIAM D. and JURA, GEORGE
Surfaces of solids. XIII. A vapor adsorption method for the determination of the area of a solid without the assumption of a molecular area, and the areas occupied by nitrogen and other molecules on the surface of a solid. J. Am. Chem. Soc. 66:1366-1373. 1944.

An extremely simple method has been developed for the calculation of the surface area of a solid from the adsorption isotherm. This method gives directly the area of the solid without the assumption of a molecular area for the adsorbate; that of Brunauer, Emmett and Teller (B.E.T.) does not give the area of the solid, but does give the number of molecules in the completed first monolayer. The agreement between values obtained by this new method and those calculated by the B.E.T. theory by the use of Emmett and Brunauer's area for the nitrogen molecule, is very close. The apparatus used for the determination of an adsorption isotherm is described.

109. HARPER, J. C. and TAPPEL, A. L.
Freeze-drying of food products. Advances in Food Research 7:171-234. 1957.

The present practices in freeze-drying are reviewed. The fundamentals of freeze-drying are stated. The application of freeze drying to food products is surveyed.

110. HAWTHORNE, J. R.
Dried egg. II. The effect of moisture content on the initial quality of spray-dried whole egg and deterioration during storage. J. Soc. Chem. Ind. 62:135-137. 1943.

In a series of samples prepared on a small spray-dryer no correlation was found between flavour and the moisture content of freshly dried egg. Only when the moisture content was below a certain critical value was there any correlation between moisture content and solubility in potassium chloride solution or beating power. Deterioration of spray-dried egg during storage, as judged by loss of solubility or beating power, was correlated with moisture content. Samples with a high moisture content also tended to deteriorate in flavour more rapidly than those with low moisture content.

111. _____ and BROOKS, J.
Dried egg. VIII. Removal of the sugar of egg pulp before drying. A method of improving the storage life of spray-dried whole egg. J. Soc. Chem. Ind. T63:232. 1944.

Spray-dried whole egg deteriorates during storage at a rate increasing with increasing temperature. At "high" temperatures the deterioration is rapid and serious; for example less than six weeks' storage at 37°C produces marked changes in the powder. These changes are loss of solubility and beating power, lowering of the pH, development of fluorescence and creaming, and browning of the powder associated with development of a burnt taste and odour. A method of retarding some of these changes by addition of certain carbohydrates to the pulp before drying has already been reported; an alternative method of retarding deterioration during storage is described in this paper.

112. HEARNE, J. F. and TAPSFIELD, D.
Some effects of reducing, during storage, the water content of dehydrated strip potato. J. Sci. Food Agr. 7:210-220. 1956.

The effect of various levels of moisture content of dehydrated potato on the relationship of 'total' and 'free' sulphur dioxide contents has been studied and the influence of these relationships on the

development of non-enzymic browning has been noted. The use of 'in-package' desiccants to reduce moisture contents reduces the rate of loss during storage of the total sulphite previously added to the potato. Free sulphur dioxide is also found to decrease during storage until the moisture content reaches a critical low value. At or below this moisture level, loss of 'free' sulphur dioxide is prevented, and in fact at moderate temperatures of storage it may actually increase. It is suggested that for potatoes of the variety and condition tested, the onset of non-enzymic browning would be delayed beyond 52 weeks by ensuring that 'free' sulphur dioxide levels were maintained at not less than 250 p.p.m.

113. HEBERLEIN, D. G. and CLIFCORN, L. E.
Vitamin content of dehydrated foods. Effect of packaging and storage. Ind. Eng. Chem. 36:912-917. 1944.

Dehydrated fruits and vegetables packaged in metal containers in an inert gas, in air, and in paper cartons, and stored at room temperature, 98°F, and 130°F, have been studied with regard to vitamin stability over a storage period of one year. The beneficial effect of inert gas packaging on carotene and ascorbic acid has been overshadowed by losses due to elevated temperatures of storage. Increased storage temperature had a detrimental effect on thiamine retention. Riboflavin in dehydrated products appears to be quite stable.

114. HECKLY, R. J.
Rapid and precise measurement of moisture in biological materials. Science 122:760-761. 1955.

Measurement of moisture in biological materials. The water content of biological materials is determined manometrically, the sample measured never being exposed to the atmosphere. The water content is calibrated in terms of the oil used in the manometer; calibration formula is given as well as the design of the apparatus. The possible uses include determination of moisture in foods, pharmaceuticals, etc.

115. HEISS, R.
Origin and prevention of undesirable flavor changes in oat products during storage. Food Technol.12 (12):688-692. 1958.

To obtain oat products free from bitter flavor, a peroxidase test is a good control method. By varying the moisture content and the temperature during steaming in conjunction with a fixed peroxidase inhibition, one may vary the flavor of the oat product and obtain the necessary harmony of flavor and aroma. The keeping quality of oat products during storage is influenced more by the moisture content than by the reduction of the peroxidase activity by the steam treatment. Oxidative rancidity of oat oils is no problem within the storage period examined for steamed oats.

116. HEISS, RUDOLF and PURR, ARNULF
Quality changes in oat products. V. Connection between storage effects on taste of oat products and the technological variants in preparations and storage as well as analytical observation of chemical changes. Deuts. Lebensm. Rundschau 50:186-192, 225-229, 1954.

The degree of moisture during storage appears to be the decisive factor in the development of fat soluble and water soluble substances in oatmeals. Sterilization of the oatmeals limits but does not inhibit taste changes; irradiation or storage in a nitrogen atmosphere is without effect. Any free fatty acids at initially low moisture levels are probably related to an autocatalytic lipolysis. Low moisture content is best for maintenance of an antioxigenic state during storage.

117. HEISS, R. and SCHACHINGER, L.
The storage of hard caramels. I. Changes at the surface layer. Stärke 5:152-157, 1953.

Caramels containing sucrose with invert sugar or starch sirup were stored under varying relative humidities (R.H.); the stickiness and water uptake were measured and the extent of sucrose crystalline was observed. Up to 35% R. H., H_2O absorption was small, giving no sticky film and little or no crystallin. At 35-40% R. H. a very sticky film was formed. At 40-50% R. H. crystallin proceeded rapidly, the stickiness and H_2O decreasing especially at 50% R. H. Above 65% R. H. the H_2O absorption increased rapidly giving sticky soft crystals which disolved entirely above about 80% R. H.

118. HEISS, R.
Uber die Geschmacksveränderungen von Hafererzeugnissen bei der Lagerung und deren Beeinflussung. Deut. Lebensm. Rundschau 48(7):129-133, (8):160-165. 1952

Deterioration of oat products can occur three ways: by becoming bitter, by hydrolytic and by oxidative rancidity. Measurement of the peroxidase activity is a suitable criterion for the control of enzyme activity during heat treatment of oat products. The effects of variety, time, temperature, and water content on taste during preparation was studied.

119. [illegible]
Über die Qualitätsbeeinflussung von Hafererzeugnissen (II.) Versuche zum Studium und zur Verbesserung der Vorgänge in der Grossdarre. Deut. Lebensm. Rundschau 49(3):57-59. 1953.

Tests were conducted to measure the variations in temperature, water content, and peroxydase activity during the course of dehydration of oat products. By controlling these factors during processing, the quality of the dehydrated product can be controlled.

120. HEISS, R.
Untersuchungen über die Haltbarkeit verpackter feuchtigkeitsemplfindlicher Güter. Keeping quality of packaged moisture-sensitive materials. Chem. Ing. Tech. 28(12):763-768. 1956

Keeping quality can be determined from a knowledge of the water-vapor transmission of the package arrangement (including seams and folds) and the sorption isotherms of the packaged materials, that is, foods, etc. Some results are reported and a number of equations are presented. Discussed are: changes in packaged goods, water-vapor permeability of packaging materials, seals, folds, and finished package.

121. HENDEL, CARL E., BURR, HORACE K. and BOGGS, MILDRED M.
Factors affecting storage stability of potato granules. U. S. Bureau of Agr. and Indus. Chem. AIC-303. 8p. 1951.

Deteriorative changes in sulfited potato granules (mashed potato powder) during storage have been studied as functions of moisture content, oxygen content of the package atmosphere, and type of container (permeable vs. impermeable). Both nonenzymatic browning and development of an oxidative off-flavor occurred slowly at 24°C. (75°F.). The latter change was accelerated (a) by lower moisture content over the range of 3.7 to 11.2 percent moisture, (b) by increasing oxygen content of the package atmosphere, and (c) to some extent by the use of a permeable container. The fact that both oxidative off-flavor development and oxygen absorption were somewhat retarded by petroleum ether extraction before storage indicates that the oxidative change occurs in the fat fraction of the potato.

122. HENDEL, CARL E., BAILEY, GLEN F. and TAYLOR, DORIS H.
Measurement of nonenzymatic browning of dehydrated vegetables during storage. Food Technol. 4(9):344-347, 1950.

Methods are presented for measuring degree of non-enzymatic browning in dehydrated white potato, carrot, cabbage, sweet potato, and onion. These methods are based on extraction of soluble colored materials from suitably ground samples, followed by clarification of the resultant extracts and photometric evaluation of the extracted color. Degree of browning is taken as the difference between optical density values for samples before and after storage.

123. _____and LEGAULT, R. R.
Observations on rate of in-package desiccation. Food Technol. 8(4):189-191, 1954.

Observations on rate and extent of in-package desiccation of 5 dehydrated vegetables at temperatures of 75°, 100°, and 120° F. (24°, 38°, and 49° C.) are reported.

Increases in rates of desiccation of approximately 2- to 3-fold per 18°F. (10°C.) of temperature increase were found. The implications of the results obtained are discussed.

124. HENDEL, CARL E., SILVEIRA, VERNON G. and HARRINGTON, W. O. Rates of nonenzymatic browning of white potato during dehydration. Food Technol. 9:433-438. 1955.

To obtain information for use in dehydrator design, rates of nonenzymatic browning have been determined for white potato half-dice held at a series of constant moisture levels and temperatures encompassing the ranges encountered in commercial dehydration. Heat damage, moisture level, and piece temperature were also measured for half-dice in a series of cabinet-drying runs. The data can be used in estimating effects of various alternatives in dehydrator design and operation. On the basis of such estimates, the significance of conditions at the finishing end of dehydration is discussed.

125. HENICK, A. S. Oxygen problem in dehydrated foods. Research and Development Association, Food and Container Institute. Activities Report 13(4):200-209. 1961.

Freeze-dehydrated items were used in experimental work carried on by the military. Areas studied were: Fat oxidation in model systems, enzyme catalysis of oxidative deterioration, and interaction of protein with breakdown products of lipid oxidation. (From Nat. Agric. Lib., Library list no. 77, 1963)

126. HENRICKSON, R. L., BRADY, D. E., GEHRKE, C. W. and BROOKS, R. F. Dehydrated pork studies. Removal of glucose by yeast fermentation. Food Technol. 9:290-292. 1955.

Laboratory trials indicated that the storage life of dehydrated pork can be extended by reducing the glucose content. The size of the meat particles influenced the fermentation rate of glucose. When meat particles of 1/8-inch-grind were used, approximately 50 percent of the glucose was removed. Fermenting the meat with 5 or 10 percent yeast for 4 to 8 hours yielded a desirable product. When cooked meat was fermented, then dehydrated, the shelf life of the dehydrated product was further improved.

127. HENRICKSON, R. L., BRADY, D. E., GEHRKE, C. W. and BROOKS, R. F. Dehydrated pork studies: removal of glucose by glucose-oxidase enzyme. Food Technol. 10:1-3. 1956.

Glucose-oxidase enzyme was used with food grade hydrogen peroxide to prepare dehydrated pork of reduced glucose content. The available

glucose was oxidized to gluconic acid. Meat particles of a 1/8 inch grind were best suited for this type of reaction and yielded a finished product with an extended shelf life. Four milliliters of liquid enzyme and 5 ml. of peroxide (30%) were added to each 1000 g. of meat. The optimum reaction time was 4 hours at 13°C. (55°F). Reacting the meat more than four hours with the enzyme did not improve its shelf life. Nearly 25% more of the glucose was converted to gluconic acid when cooked pork was reacted with the enzyme as compared to that which was uncooked. The taste panel found the enzyme-treated meat superior to the control.

128. HENRY, KATHLEEN M., KON, S. K., LEA, C. H. and WHITE, J. C. D. Deterioration on storage of dried skim milk. J. Dairy Res. 15:292-363. In 6 parts. 1948.

Dried skim milk of low, medium and high moisture contents packed in air and in nitrogen were stored at 20°, 28.5° and 37°C for nearly two years. Tests were made on samples for chemical, physical and palatability changes and changes in the biological value of the proteins. Microbiological assays of essential amino acids were made. Little change was observed in the powders of low and medium moisture content except in palatability and gas exchange at the higher temperatures. The powder of the highest moisture content, particularly at the higher storage temperatures, rapidly became unpalatable, discolored and insoluble. The major cause of this deterioration is a reaction between the free amino-acid groups of the milk protein and reducing sugar. Evidence was also obtained of an oxidative reaction which produced 'off'-flavor in powders stored for long periods at moisture contents too low for the protein-sugar reaction to occur. There was a general parallelism between several of the chemical criteria measured and palatability, although no single chemical test correlated satisfactorily.

129. HERRMANN, KARL
Die Gefriertrocknung des Fleisches und anderer tierischer Produkte. (The freeze-drying of meat and other animal products) Fleischwirtschaft 13(9):730-732, 735-736. 1961.

Based on the literature, a survey is given of the state of freeze-drying of animal products, especially meat. The procedure is extremely suitable for drying meat because it protects the meat to be dried as does no other procedure. The biochemical changes which occur during subsequent storage are discussed in detail. For a quality product there are important factors, among which are a low-as-possible residual water content (about 2%) and suitable packaging. Until now the procedure was too expensive to be used to a large extent. Yet some areas of industrial use can already be seen.

By modifying the procedure, the drying periods may be shortened. Also, improved equipment might contribute to reducing costs.

130. HICKEY, F. D. and ADAMS, H. W.
Moisture absorption rates of cereals and cereal fractions and surface area of common cereals. Food Machinery and Chemical Corporation, San Jose, California, 12p. May 13, 1958.

Moisture absorption rates in a laboratory analog of a continuous steeping apparatus have been found to be a linear function when plotting log steeping time against log moisture content in percent. This data is shown. The rate is probably a function of surface area, temperature of the liquid absorbed, interfacial tension of liquid absorbed and diffusivity of liquid in the absorbing cereal. The moisture absorption rate data given here has been successfully used as a processing guide to the continuous pressure cooking of cereals in three laboratories.

131. HILL, TERRELL L.
Statistical mechanics of adsorption. V. Thermodynamics and heat of adsorption. J. Chem. Phys. 17:520-535. 1949.

The thermodynamics of an adsorbate on an inert adsorbent is discussed in some detail. Heats of adsorption are given particular attention in an attempt to clarify and extend the available methods in this field. It is found that the true equilibrium $\Delta H = T\Delta S$ of adsorption for adsorbate molecules is given by

$$(\partial \ln p/\partial T)_{\varphi} = -\Delta H/RT^2,$$

where φ is the two-dimensional spreading pressure. The relation of the work of Rowley and Innes to the present paper is considered.

132. HODGE, JOHN E.
Chemistry of browning reactions in model systems. J. Agr. Food Chem. 1(15):928-943. 1953.

Many different types of organic reactions lead to the production of brown pigments at moderate temperatures. In spite of many reviews of the subject, there has been no comprehensive organization of the reactions. In this review some relationships are shown to exist among the carbonyl-amino, the nonamino, and the oxidative types of browning. Recent findings have provided the basis for an integration of the several isolated partial theories of browning (Maillard, sugar fission, ascorbic acid, furaldehyde) heretofore proposed. The significance of the occurence of the Amadori rearrangement in the Maillard reaction is stressed, and a mechanism for browning in sugar-amine systems

based upon the rearrangement is outlined. Attention is directed to the little-studied but important role of dehydrogenated reductones in both enzymatic and nonenzymatic browning reactions. Investigations of browning reactions in model systems during the past 3 years are reviewed, with the pertinent older studies, and the results of most of these are shown to fit into the proposed scheme of reactions. A classified directory to the major part of 201 references on browning in nitrogenous model systems (1940 to March 1953) is included.

133. HOFER, A. A. and MOHLER, H.
Apparatur zur Messung der Sorptionskinetik und eine Mikromethode zur Messung von Sorptionsisothermen. Helv. Chim. Acta 45(5):1415-1418. 1962.

An apparatus for the automatic determination of the kinetics of sorption and desorption which is based on the Cahn electrobalance is described. With the same balance the micro-determination of sorption isotherms is also possible.

134. _____
Zur Aufnahmetechnik von Sorptionsisothermen und ihre Anwendung in der Lebensmittelindustrie. Mitt. Lebensm. Hyg. Bern 53(4): 274-290. (Technique of registration of (moisture) absorption isotherms, and their application in food industry.) 1963.

Descriptions are given of the balance method of Beever et al, the isoteniscope balance method of McBain, the LiCl method of Mossel, and the Legault manometer method: all four methods give the same results (cf. Mohler, ibid., 1961, 52:526). The fully automatic Cahn electric balance (described) has been applied by the authors to the measurement of rates of absorption by micro-determinations (cf. Helv. Chim. Acta, 1962, 45:1415). Very low moisture % render freeze-dried foods liable to oxidation, whilst high % promote Maillard reactions. Curves are given showing the relationship between the moisture % of freeze-dried foods and the ratio of the water v.p. above the sample to the v.p. of pure water at 20°. The part of the (S-shaped) curve representing the initial (monomol.) uptake of moisture by the anhyd. products represents the most favourable phase for protection against oxidation. It is shown (a) that heat-denaturation decreases the absorptive capacity of starch, (b) that impregnation with fat decreases the absorptive capacity of freeze-dried cauliflower and veal, and (c) that impregnation with sol. starch increases the capacity of dried cauliflower. Impregnation with fat also protects the powders against oxidation and crumbling. The effects of drying beef under different conditions are examined. The results are considered in the light of the B.E.T. concept (cf. Brunauer et al, J. Amer. Chem. Soc.60:309, 1938.)

135. HOGAN, JOSEPH T. and KARON, MELVIN L.
Hygroscopic equilibria of rough rice at elevated temperatures. J. Agr. Food Chem. 3(10):855-860. 1955.

The hygroscopic equilibria of rough rice have been determined at 80° to 111°F for moisture contents of 11 to 22%, dry basis. The data have been correlated by an Othmer plot in which temperature, moisture content, and vapor pressure data are presented graphically for use in storage, packaging, processing, and drying. The plot permitted calculation of the relative isosteric heat of adsorption of water by rough rice of varying moisture content. Hygroscopic data were examined by the Harkins-Jura equation, which indicated that adsorption of water occurs as a condensed film over 14 to 22% moisture content. Application of the Brunauer-Emmett-Teller equation to available data on rough rice indicated that adsorption of moisture as a unilayer occurs over a range from dryness to approximately 7% moisture content. The amount of water, which constitutes a unilayer of adsorbed water on rough rice, is approximately 7 grams per 100 grams of dry rough rice and is identical calculated by Harkins-Jura or Brunauer-Emmett-Teller equations. Adsorption of water on rough rice occurs in three stages. The first, 0 to 7% moisture content, represents a unilayer of water molecules; the second is characterized by addition of an equal number of molecules to the already adsorbed unilayer; and the third may be considered a multilayer addition of water from approximately 14% moisture to saturation.

136. HOOVER, SAM R. and MELLON, EDWARD F.
Application of polarization theory to sorption of water vapor by high polymers. J. Am. Chem. Soc. 72:2562-2566. 1950.

The equation $\ln p_o/p = K_2 K_1^{a}$ (in which K_1 and K_2 are both dependent on the temperature), derived by Bradley to describe the sorption of gases on polar sorbents through dipole propagation, fits the experimental data for the sorption of water on a variety of high polymers. Results on casein, benzoylcasein, silk, polyglycine, wool, ovalbumin, cotton, mercerized cotton, nylon and viscose rayon are presented as straight line functions ($\log \log p_o/p$ v.s. $a \log K_1$). The average deviation of the experimental points over the range of 6 to 93% relative humidity is 0.28 g. of water per 100g. dry weight, or 3.7% for the authors' data on the first eight substances.

The application of this equation to sorption of water on polar groups, and the value of this linear relationship in analyzine sorption data, are discussed.

137. HOUSTON, DAVID F., HUNTER, IRVING R., McCOMB, ELIZABETH A. and KESTER, ERNEST B.
Cereal storage effects. Deteriorative changes in the oil fraction of stored parboiled rice. J. Agr. Food Chem. 2(23):1185-1190. 1954.

Changes in the oil fraction of stored parboiled rice have been followed as criteria of loss in quality. Storage of parboiled rice in the dark at several temperatures permitted a study of rancidification and of nonenzymatic changes in the oil as measured by peroxides, monocarbonyl compounds, and free acids. In open-container storage, values for peroxides, monocarbonyls, and free acids remain low during an induction period, then rise markedly at or just before the time rancid odors appear. Peroxides and monocarbonyls again decrease to low residual values and rancidity disappears. Free acid values remain at the higher level. Original moisture contents of 11.4 to 12.5% fall to about 10% at 77°F, 6% at 100°F, and 3% at 140°F. Storage lives of two parboiled rices show the same relative order at 77°, 100°, and 140°F. Monocarbonyl maxima occurring at about 1 year at 77°F are found after about 1 month at 140°F and 1 week at 180°F. This observation may serve as a basis for accelerated testing of storage life.. In closed storage at 77° and 100°F peroxide and monocarbonyl changes are similar to those for open storage, though induction periods are longer. At 140°F no rise is shown. Free acidity increases linearly for considerable periods at all three temperatures. The rancidifying effect of light on fat-containing foods was confirmed for parboiled rice during storage at 77°F.

138. HOUSTON, D. F., STRAKA, R. P., HUNTER, I. R., ROBERTS, R. L. and KESTER, E. B.
Changes in rough rice of different moisture content during storage at controlled temperatures. Cereal Chem. 34 (6):444-456. 1957.

Caloro rough rice samples containing 11.2, 13.8,15.3, and 16.5% moisture were stored in loosely covered cans containing humidifying solutions for 7 months at 70°F (21°C) and 90°F (32°C) and tested monthly for moisture, odor, viability, milling yield, free acidity, monocarbonyl compounds, total and reducing sugars, and counts of molds, yeasts, actinomycetes, and aerobic and anaerobic bacteria.

Changes in characteristics occurred more quickly and more extensively as moisture content or temperature increased, but milling yields remained unchanged until quality had seriously deteriorated. Only the two low-moisture rices at 70°F (21°C) remained free from sourness. Oxidative changes were not detected.

Populations of actinomycetes, bacteria, and yeasts decreased under all storage conditions, though yeast reductions were small at 70°F (21°C) for rice of 11.2 and 13.8% moisture. Molds increased

in the two high-moisture rices, extensively at 16.5% moisture at both temperatures. Nonreducing sugars decreased during storage, whereas reducing sugars and free acidity increased. Acid increases were logarithmic with time, and the rates increased approximately exponentially with moisture content of the rice. Percentages of germination and nonreducing sugars and log of free acidity, representing the three most sensitive characteristics, were closely related and had high coefficients of linear correlation. Changes in these storage effects also showed trends in agreement with mold growth, a potential cause.

139. HOUSTON, D. F., HUNTER,I. R. and KESTER, E. B.
Effect of steaming fresh paddy rice on the development of free fatty acids during storage of brown rice. Cereal Chem. 28:394-399. 1951.

The rates of free fatty acid development at 25°C (77°F) have been determined in brown rice prepared from portions of freshly harvested moist paddy rice (21.9% H_2O, wet basis) which had been steamed various lengths of time at 88°, 93.5°, and 100°C (190°, 200°, and 212°F) before drying. The free fatty acids in the oil of the first storage series (13.4 to 13.9% H_2O), steamed 5 and 15 minutes at the three temperatures, increased by 2.1 to 2.9% during 140 days' storage compared with 10.0% for the unsteamed control (13.9% H_2O). The second series (12.9 to 13.4% H_2O), steamed 1, 2, 3, and 4 minutes at 100°C. (212°F), increased by 1.7 to 2.1% in the same time and 5.7 to 5.8% in 285 days. The control (15.2% H_2O) showed an increase of 14.3% at 140 days and 13.8 % at 285 days. Enzyme inactivation appeared essentially complete in all steamed samples.

The fatty acid development in the brown rice from steamed paddy followed an auto-catalytic curve that can be expressed by $dF/dt = k(F)(100-F)$, where F is the percentage of free fatty acid in the oil, (100-F) the percentage of unhydrolyzed oil, and t the time in days.

Additional effects of the steaming treatment are: (a) slight improvement in milling quality, (b) complete loss of viability, and (c) more rapid development of rancidity, as evidenced by peroxide numbers after 140 days' storage of 39.8 to 80.0 for the oil of samples in series No.1, compared with 21.9 for the control.

140. HOUSTON, DAVID, F.
Hygroscopic equilibrium of brown rice. Cereal Chem. 29:71-76. 1952.

Equilibrium moisture contents of Caloro brown rice at 25°C (77°F)

have been determined for atmospheric relative humidities of 11 to 93%, together with the rates of approach to equilibrium. Moisture contents at 10% R.H. increments, beginning at 10%, are: 6.2, 8.0, 9.5, 10.9, 12.3, 13.5, 14.8, 16.2, and 19.1%.

The extent of hysteresis effects in sorption of moisture by the brown rice is indicated by the fact that rice brought to equilibrium at 40 to 65% relative humidity from a dry condition attains a moisture content 0.7 to 1.0% lower than that resulting from direct drying of moist rice to the same relative humidity.

141. HOUSTON, D. F. and KESTER, E. B.
Hygroscopic equilibria of whole-grain edible forms of rice. Food Technol. 8:302-304. 1954.

Equilibrium moisture values have been determined for parboiled and quick-cooking rices at 77°F. (25°C) and for parboiled rice at 100°F (37.8°C) at atmospheric relative humidities of 11 to 93%. Comparisons are made with reported values for brown and white rice at 77°F. and quick-cooking rice at 100°F.

Hysteresis effects are greater on quick-cooking and parboiled rices (processed with moist heat) than on raw white and brown rices. Up to about 80% R.H. at 77°F., the moisture equilibria of quick-cooking rice are lower than those of other rices. In the same R.H. range, a temperature rise from 77° to 100°F. lowers the equilibrium moisture of parboiled and quick-cooking rices by 1 to 2%.

142. HOWARD, LOUIS B.
Desiccants improve dry packs. Food Packer 26(4):31. 1945.

The use of desiccants in sealed cans of dehydrated vegetables promises to economically solve the problem of increasing the keeping quality of the product by lowering the moisture content. Accelerated tests have indicated that several years may elapse before appreciable deterioration will occur in packages containing desiccants held at common storage temperatures.

143. HOWARD, L. B.
Factors of processing and storage that affect quality, Canner 100(13):46-50, 1945.

Experiments on the factors that affect storage were set up on commercially-produced food material which had been dried to three different moisture levels and stored under four or five different temperature conditions. The changes which occurred during storage

were measured for palatability, vitamin content, loss of sulfite when used, color change, evolution of carbon dioxide, ease of reconstruction and other characteristics. To attain the desired low moisture levels without radically changing the dehydration process or damaging the product, it is suggested that a desiccating agent be placed in the package with the product. Calcium oxide is the simplest and most practical to use at the present time.

144. HUANG, I- YIH and DRAUDT, H. N.
Effect of moisture on the accumulation of carbonyl-amine browning intermediates in freeze-dried peaches during storage. Food Technol. 18(8):124-126 (1234-1236). 1964.

Freeze-dried Georgia cling and California Royal cling peaches stored at different moisture levels for 550 and 138 days were examined by paper chromatography for sugar-amine browning intermediates. Browning intermediates that appear to be fructose-aspargine, fructose-aspartic acid, and a reaction product of ammonia and D-glucose were detectable at 138 days of storage at 28°C in freeze-dried peaches with moisture contents of 1.68% and above, but not in those containing 0.55% moisture.

145. HUBBARD, J. E., EARLE, F. R. and SENTI, F. R.
Moisture relations in wheat and corn. Cereal Chem. 34(6):422-433. 1957.

Hysteresis loops were established for wheat and corn at 25°, 30°, and 35°C over the range 0 to 97% relative humidity. Both desorption and adsorption isotherms for corn and wheat were found to be sigmoid. The maximum hysteresis effect was found between 12 and 44% humidity .. amounting to 1.6% and diminishing to less than 0.2% at 92% humidity.

No consistent differences were found in the extent of hysteresis with temperature changes over the range of temperatures studied. Hygroscopic capacity of grain shows a negative correlation with temperature, a rise in temperature of 10°C lowering the equilibrium moisture content by as much as 1.3%.

The equilibrium relative humidity of the interseed air as measured with an electric hygrometer and the moisture content as measured with an electric moisture meter were determined on 114 commercial samples of wheat and corn. Values found were shown to lie, for the most part, in the expected range of the hysteresis loops established.

Observations were made on the relative importance of moisture content of grain or relative humidity of interseed air near the critical levels for mold growth.

146. HULSE, J. H.
Food defense research in Canada. Research and Development Association, Food and Container Institute Activities Report 12(2):64-71, 1960.

With regard to freeze-drying, the article describes the unique process, laboratory studies on perfecting its techniques, on producing satisfactory foodstuffs, on rancidity factors, and storage problems, as well as packaging research. (From Nat. Agric. Lib., Library list no.77, 1963.

147. HUMMEL, B. C. W., CUENDET, L. S., CHRISTENSEN, C. M. and GEDDES, W. F.
Grain storage studies. XIII. Comparative changes in respiration, viability, and chemical composition of mold-free and mild-contaminated wheat upon storage. Cereal Chem. 31:143-150, 1954.

Experiments with a western white wheat, free from internal molds, have made it possible to secure direct experimental evidence on the relative magnitudes of deteriorative processes inherent in the seeds themselves and those produced by the normal microflora on and within the seed.

The respiratory rates of mold-free wheat at 35°C and moisture levels ranging from 15 to 31% were low and constant with time. In contrast, the respiration of the moldy wheat markedly increased after a few days. Loss in viability was enhanced by mold growth, although all samples stored at moisture levels exceeding 18% were nonviable. Large increases in fat acidity and decreases in nonreducing sugars occurred in the moldy samples but only slight changes were observed in the mold-free wheats.

These studies provide direct evidence of the importance of molds in the deterioration of stored grain.

148. HUNT, SHEILA, M. V., and MATHESON, N. A.
The effects of dehydration on actomyosin in fish and beef muscle. Food Technol. 12:410-416. 1958.

Changes which occur in actomyosin of beef and cod muscle as a result of dehydration have been investigated. Three criteria of denaturation have been used, namely, loss of solubility in salt solutions, loss of contractility of muscle fibres in presence of adenosine triphosphate and loss of adenosine triphosphatase activity. On dehydration, cod actomyosin becomes insoluble and the muscle fibres may or may not lose their power to contract, though about half the adenosine triphosphatase activity is not destroyed. Muscle fibres in the

dehydrated beef examined were always contractile after reconstitution and they too retained about half their adenosine triphosphatase activity. These results are interpreted as being due to stepwise denaturation of actomyosin.

149. HUNT, SHEILA, M. V. and MATHESON, N. A.
The relationship between the quality of dehydrated raw beef and the adenosine triphosphatase activity after storage at various moisture contents, Food Res. 24:262-270, 1959.

The tests were carried out with raw beef dried by the accelerated freeze-dry process. The results of the tests are accompanied by discussion of their practical and theoretical implications. (From Nat. Agric. Lib., Library list no. 77)

150. HUNTER, I. R., HOUSTON, D. F. and KESTER, E. B.
Development of free fatty acids during storage of brown (husked) rice. Cereal Chem. 28:232-239. 1951.

Development of free fatty acid in commercially dehulled Caloro brown rice stored 22 weeks at moisture levels of 3.9, 6.6, 9.5, 11.8, and 14.1% (wet basis) and at temperatures of 0° to 2°, 25° and 35°C (32° to 35.5°, 77° and 95°F) increased with the moisture content and temperature of storage. An increase in free fatty acids of approximately 1% per month resulted at 0°C. (32°F) in rice containing 14.1% moisture, and at 25°C (77°F) in rice with 6.6% moisture. At 25°C (77°F) the initial rates of acid formation were reduced about four-fold by lowering the moisture content from 14.1 to 9.5% and sixteen-fold by drying to 3.8%. Two portions of a separate lot of Caloro brown rice, prepared in the laboratory from paddy rice stored 7 weeks at 1.5°C (35°F) with 21.9% moisture, were dried to 13.9% and 15.2% moisture and stored at 25°C, (77°F). Development of free fatty acids was generally similar to that of the first lot. Observed differences indicate possible variations in a single variety of rice under differing cultural, storage, and milling conditions. Other varieties would be expected to give similar results.

151. HURD, CHARLES D. and BUESS, CHARLES M.
The browning reaction of sugars and amino acids approached by means of simple hydoxy ketones. J. Am. Chem. Soc. 78:5667-5671, 1956.

Benzoin reacts with benzylamine or pentylamine at 100° to yield α-(benzylamino)-desoxybenzoin and α (pentylamino)-desoxybenzoin, respectively, whereas at 170° benzylamine gives rise to N, N'-dibenzyl-1, 2-diphenyl-1, 2-ethanediimine, the latter compound also being formed by reaction of benzil and benzylamine together with some concurrent oxidation of benzylamine to the aldehyde state. Some

oxidation of benzoin occurs on heating benzoin with 2-aminoethanol. The reaction of benzoin with α-amino acids at 165-175° causes evolution of carbon dioxide, formation of tetraphenylpyrrole by an aldolization process, and of tetraphenylpyrazine by an oxidation process. Benzoin, acetophenone and glycine at 175° yield 1-methyl-2, 3, 5-triphenylpyrrole. Acetol and phenacyl alcohol (both primary alcohols) react with α-amino acids to form brown products preceded by yellow and orange stages, and pyrazines are obtainable from the products. Acetoin (a secondary alcohol) reacts more slowly but both yellow and brown stages are reached; propionoin does not react beyond the orange stage. Oxidation of the brown polymers from acetol-phenylalanine revealed a 4:1 ratio of acetol to amino acid residues in the polymer. The general problem of browning of carbohydrates by amino acids or proteins is considered and an explanation is offered based in large measure on results with the model systems. The steps proposed to explain the colored bodies involve an Amadori rearrangement of aldose to the N-analog of the ketose, aldolization and/or oxidation to yield polymers containing cumulative carbonyl groups (α-diketones, triketones, etc.).

152. HUTCHINSON, J. B., MARTIN, H. F. and MORAN, T.
Location and destruction of lipase in oats. Nature 167:758-759. 1951.

The oil content of British oats has been found to vary between 4.5 and 11% by weight of dry matter of the kernel. In normal storage of oats at 13% moisture content and a storage temperature up to 18°C the free fatty acid content of the oil increases very slowly. But if the grain is crushed or milled into meal, the production of free fatty acid within two or three days is quite appreciable. The hydrolytic agent is an enzyme of the lipase type, and it is destroyed within a few minutes if the oat or meal is heated to 90-100°C, provided the moisture content does not fall below about 12%. Adequate steaming of oats during the manufacture of oatmeal or oatflakes is one method of destroying the lipase. The bulk of the active lipase in oats lies within the pericarp, that is, above the testa and not in the aleurone layer. Removal of this layer can reduce lipase activity by 98%.

153. HUTTON, E. A. and GARTSIDE, JOAN
The moisture regain of silk. i. Adsorption and desorption of water by silk at 25°C. J. Text. Inst. Trans. 40T:161-169. 1949.

The adsorption and desorption isotherms at 25°C have been determined for Japanese, Chinese, and Italian silks, both in the gum and after degumming. The degummed silk has a lower regain than the

corresponding silks in the gum at all humidities and also show less hysteresis between the adsorption and desorption isotherms. When degummed, the different kinds of silk absorb water to the same, or nearly the same, extent but in the gum state the adsorption is greater for the Italian silk than for the Japanese and Chinese silks. Slightly lower values were found for the regain of "iso-electric" degummed Japanese silk than for the same silk before treatment. Approximate values for the regain of sericin have been deduced.

154. ILLIES, R. and LINDERMANN, E.
The moisture absorption of hard candy related to the starch syrup and polymerization degree of dextrines used. Starke 5:119-124, 1953.

The rate of absorption of moisture at 20° and 70% relative humidity depends mainly on the amount of glucose present, maltose and especially dextrins being less hygroscopic.

155. INGLES, D. L. and REYNOLDS, T. M.
Chemistry of non-enzymic browning. IV. Determination of amino acids and amino acid-deoxyfructoses in browned freeze-dried apricots. Australian J. Chem. 11(4):575-580. 1958.

1-(N-Amino acid)-1-deoxyfructoses have been determined by elution chromatography on columns of a buffered cation exchange resin following the method described by Moore and Stein for the determination of amino acids. This method has been used to determine the free amino acids and ammonia in freeze-dried apricots before and after storage for 12 months at 25°C and 70 percent.R.H., as well as to determine the 1-(N-amino acid)-1-deoxyfructoses and related compounds formed during storage. The total free amino acid decreased by 61 percent and the ammonia by 9 percent, the changes in individual amino acids ranging from 22 to 81 percent. The amino acid-deoxyfructoses and related compounds accounted for 90 percent of the free amino acid lost, the actual discrepancy being 1.2mM/100 g dry weight of fruit.

156. INGLES, D. L. and REYNOLDS, T. M.
Chemistry of non-enzymic browning. IX. Studies of sugar mono-esters of malic acid found in browned freeze-dried apricots. Australian J. Chem. 12(3):483-490, 1959.

Mono-esters of glucose, fructose, and sucrose were prepared by heating the unsubstituted sugar with DL-malic acid. Chromatographic separations showed that four esters were formed from both glucose and fructose and six from sucrose. Three glucose esters were obtained

chromatographically pure and two of these gave brucine salts, one crystalline. Periodate oxidation and acid strengths showed that these esters were glucose 1-α-,6-α-, and 6-β-hydrogen malates. One fructose ester was obtained chromatographically pure and shown to be fructose 6-β-hydrogen malate. Structures were assigned to the other esters on the basis of their RGlucose values and acid strengths. Structures, based on the results of partial hydrolysis with acid, were assigned to three sucrose esters. These results yield presumptive evidence for the identity of the malic acid esters detected in freeze-dried fruit (Anet and Reynolds 1957). The acids in freeze-dried fruit were determined by elution chromatographically using the formate form of an anionexchange resin. The acids and esters in freeze-dried fruit stored at 25, 37, and 50°C were similarly determined.

157. INTERNATIONAL CONGRESS OF FOOD SCIENCE AND TECHOLOGY
Report on the first. 1962, Food Manuf. 37(11):543-544, 547-549, 1962.

Coverage is selective, not comprehensive. With regard to freeze-drying research, specific, but brief, reference is made to favorable and unfavorable findings (especially concerning various vegetables), as well as to investigative work on automatic control. Attention is given to processing techniques, storage properties and packaging developments. (From Nat. Agric. Lib., Library list no. 77, 1963)

158. JASON, A. C.
A study of evaporation and diffusion processes in the drying of fish muscle. In Fundamental aspects of the dehydration of foodstuffs. p.103-135. Society of Chemical Industry, London. 1958.

The rate of drying of fish muscle during the constant-rate period is controlled solely by the conditions of the ambient atmosphere and is equal to that from a saturated surface of the same shape. The duration of the constant-rate period is related to that from a saturated surface of the same shape. The duration of the constant-rate period is related to the rate of evaporation per unit area by an expression involving the effective diffusion constant, the thickness of the sample and the free water concentration as parameters.

Drying during the falling-rate period takes place in two distinct phases, in each of which the behaviour is in accord with a solution of the diffusion equation based on Fick's Law. In each phase, drying is characterized by an effective diffusion coefficient which is independent of shrinkage of the muscle and which in the first phase is considerably greater than in the second phase. Both

coefficients vary with temperature according to an Arrhenius type of equation in which the energy of activation for diffusion is one of the parameters. The transition from the first to the second phase appears to be associated with the uncovering of the unimolecular layer of water which covers the protein molecules. Experimental evidence suggests that the process of evaporation and diffusion may be characterized by a scheme of energy levels involving the heat of adsorption of the unimolecular layer, the heat of liquifaction of water and the energies of activation corresponding to each of the two phases of the falling-rate period.

All species of non-fatty fish exhibit identical drying behaviour during both the constant-rate and the falling-rate periods.

159. JONES, N. R.
"Browning" reactions and the loss of free amino acid and sugar from lyophilized muscle extractives of fresh and chill-stored codling (Gadus callarias). Food Res. 24:704-710, 1959.

Muscle extractives, from codling stored in ice for different periods of time, have been maintained at 40°C and 60% R. H. for 3 days.

The amount of "browning" resulting from this treatment varied considerably in extractives from different fish stored in ice for the same length of time: variations between batches were small in comparison. "Browning" was accompanied by the disappearance of the limited quantities of sugar in the extractives and losses in amino acid greater than would be expected by 1:1 reaction with sugar. Glucose was the limiting factor in the "browning" of extractives from fresh codling muscle and ribose in those from spoiling muscle.

160. JONES, N. R.
Discoloration of muscle preparations from codling (Gadus callarius) by degradation products of 1-methylhistidine. Nature 177:748-749, 1956.

This communication indicates that simple compounds of imidazol type may initiate a non-enzymic discoloration of foodstuffs in the effective absence of sugar. It is not suggested that, in the presence of sugar and free amino-compounds under Maillard-reactive conditions, it is likely to be a major factor in browning. Admixture of dl-1-methylhistidine and d-ribose under such conditions gave a dark brown coloration considerably in excess of the yellow brown obtainable with the amino-acid alone.

161. JONES, N. R.
Factors affecting the free amino acid composition of fresh and iced skeletal muscle of North Sea codling (Gadus callarias). Biochem. J. 58:xlvii-xlviii, 1954.

Studies over a year on the basic amino acid composition of fresh skeletal muscle of codling agree roughly with the qualitative studies of Shewan. Seasonal variations are found in the values for certain amino acids. The free amino acid composition of the muscle of butted codling alters considerably during storage in ice. Early changes (0-4 days) appear to derive primarily from leaching by ice-melt water and action of autolytic enzymes. Later changes result from the additional effects of spoilage micro-organisms.

162. JONES, N. R.
Free sugar in chill-stored, trawled codling (Gadus callarias) muscle. J. Sci. Food Agr. 9:672-677, 1958.

Glucose is the only free sugar present in fresh codling muscle; ribose appears during chill storage. Glucose values fall during storage and, after the initial rise, ribose values also fall. The causes of these changes, and their relevance to the appearance of brown discolorations in salted and dehydrated codling, are discussed.

163. ———
Kinetics of phosphate-buffered, ribose-amino reactions at 40° and 70% relative humidity: systems related to the 'browning' of dehydrated and salt cod. J. Sci. Food Agr. 10:615-624, 1959.

The development of brown pigmentation, the disappearance of reactants and changes in the fluorescence of reaction mixtures of ribose with individual compounds present in cod muscle extractives have been measured. These data are discussed, together with chromatographic evidence, in relation to general 'browning' theory. By reference to the known composition of the extractives of fresh and chill-stored muscle, the relative importance of the different nitrogenous compounds in the early stages of the 'browning' of dehydrated and of salt cod is postulated.

164. JOSLYN, M. A.
Role of amino acids in the browning of orange juice. Food Res. 22:1-14, 1957.

The extensive data published on the browning of foods in general and particularly on the browning of orange juice is reviewed and some apparent discrepancies are explained.

The apparent decrease in lysine and glutamic acid occurring in later stages of browning of orange juice stored in presence of air for

4 years at room temperature and some evidence for the presence of ninhydrin positive amino acid compounds is reported.

New data on the oxidative browning of ascorbic acid-amino acid-sugar system is presented which indicates that ascorbic acid is the most reactive component and that glucose and fructose inhibit its browning. Amino acids in the initial stages inhibit browning, but in later stages increase it. The concentration of ascorbic acid initially present has a marked effect on rate and extent of browning of ascorbic acid solutions.

165. JOYNER, L. G.
Moisture control in sugar. Mod. Packaging 29(12):180-184, 238-240, 242, 244. 1956.

Sugar is a relatively pure crystal of sucrose with any non-sucrose material forming a coating on the surface. The moisture content is almost entirely in the form of an adsorbed surface film. If the sugar has a high moisture, the absorbed film will be a relatively thick layer of saturated solution. When this sugar is exposed to a relative humidity lower than its equilibrium point, the moisture passes into the atmosphere leaving a supersaturated solution which can solidify, causing caking. Brown sugar crystals are high in non-sucrose components and so are very susceptible to caking. To protect brown sugar from changes in humidity conditions, tests were made on liners for the packages at around 100°F and 30% relative humidity. The smallest and slowest moisture loss was obtained by a laminated foil liner, but which has a high cost. The paper selected as suitable was a laminated paper heat sealed with an over-layer of wax.

166. JULIANO, BIENVENIDA O.
Hygroscopic equilibria of rough rice. Cereal Chem. 41:191-197, 1965.

Desorption and adsorption hygroscopic equilibria of rough rice of two non-waxy (nonglutinous) and two waxy (glutinous) varieties at 27.5° and 32.5°C were measured at relative humidities between 44 and 96.5%. At 75% r.h., rough rice had equilibrium moisture contents between 12.8 and 14.3% at 27.5°C and between 12.6 and 14.2% at 32.5°C. Waxy rice had significantly higher moisture contents than nonwaxy rice at 75% and higher relative humidities for adsorption and at 84% and higher relative humidities for desorption.

167. KAPSALIS, JOHN G., WOLF, MAX, DRIVER, MARGARET and HENICK, AL, S. The moisture sorption isotherm as a basis for the study of sorption and stability characteristics in dehydrated foods. Proc. of the Sixteenth Research Conference, Research Council of the American Meat Institute Foundation, 73-93. 1964.

The moisture sorption isotherms of air dried and freeze dried beef at different temperatures were used as a basis for the calculation of the B.E.T. (Brunauer-Emmett-Teller) and Harkins-Jura "monomolecular layer" values, heats of adsorption, and surface areas. On the basis of this, differences between the two products in water "mono" and "multi-layer" coverage are discussed. It is shown that a variety of basic useful information can be derived on the basis of the moisture sorption isotherm.

In a different study, the chemical stability upon storage of raw, ground, freeze dried beef and of precooked, freeze dried shrimp was examined under controlled relative humidity conditions at different temperatures. Deterioration in beef samples as measured by all methods was greatest at 31.6% r.h. Shrimp stored at 100°F showed maximum stability at 0 r.h.

Important types of chemical deterioration include, among others, (a) protein oxidation, (b) hematin pigment oxidation (c) lipid oxidation (d) oxidative non-enzymatic browning, (e) active carbonyl-amine browning, and (f) hydrolytic changes. In this study, deterioration changes of types (a), (b), (e) and (f) were considered. It is probable that moisture conditions which favor non-enzymatic browning may be "protective" against lipid double bond type of oxidation.

168. KAREL, M. and NICKERSON, J. T. R.
Effects of relative humidity, air, and vacuum on browning of dehydrated orange juice. Food Technol. 18(8):104-108, (1214-1218), 1964.

Studies were undertaken to determine the effects of water and of oxygen on browning and loss of ascorbic acid in dehydrated orange crystals. Included was determination of water sorption isotherms at 25 and 37°C and of browning and ascorbic acid losses in crystals stored at 37°C under different conditions of relative humidity and of oxygen tensions. Oxygen had no effect on browning and ascorbic acid content, but browning and ascorbic acid destruction were faster with increasing relative humidity. All the water present in the crystals, including that adsorbed in a monomolecular layer, appeared to be available for reactions resulting in browning and destruction of ascorbic acid.

169. KAREL, MARCUS, AIKAWA, Y. and PROCTER, BERNARD, E.
New approach to humidity equilibria data. Mod. Packaging 29(2):153-156, 237, 239-240, 1955.

Report describes an electric hygrometric method for the determination of equilibrium relative humidity and compares it to the graphical interpolation method for several food products.

170. KAREL, M., AIKAWA, Y. and PROCTER, B. E.
WVP by electric hygrometer. Mod. Packaging 28(8):213-215, 322-324, 1955.

An electric hygrometer apparatus for the measurement of water-vapor permeability of food-packaging materials is described. The permeability of Mylar and Saran films was determined, using Fick's law of diffusion. It was found that the permeability was directly proportional to the vapor pressure differential and inversely proportional to the film thickness. There were no direct effects of temperature on the film. Storage for 72 hours at different temperatures and humidities had no effect on the Mylar film, but had a marked effect on Saran, the permeability of which was lessened as the temperature and humidity increased.

171. KARGIN, V. A.
Sorption properties of glasslike polymers. J. Polymer Sci. 23:47-55, 1957.

Glasslike glucose does not absorb water at low vapor pressures. Sorption begins only when the vapor pressure and the concentration of adsorbed liquid in the surface layer are sufficient to cause the glass to melt. The degree of tight packing of polymeric glasses varies considerably, decreasing with increasing molecular weight and rigidity of the chain molecules. Cellulose, which unlike tightly packed glucose sorbed water over the whole range of vapor pressures, is a typical example of a loosely packed polymer. Low molecular weight polystyrenes dissolve in ethylbenzene without any heat production and sorb ethylbenzene from the vapor at high pressures only. High molecular weight polystyrenes, however, dissolve in ethylbenzene, producing heat, and sorb ethylbenzene at all vapor pressures. Polymeric glasses hold an intermediate position between liquids and hard porous sorbents, such as silica gel, in regard to their sorbing properties.

172. KARON, M. L. and ALTSCHUL, A. M.
Effect of moisture and of treatments with acid and alkali on rate of formation of free fatty acids in stored cottonseed, Plant Physiol. 19:310-325, 1944.

Increase in H_2O content of the seed resulted in an increased rate of hydrolysis of the glycerides. The most rapid increase occurred when

the moisture content was raised above 15%. Treatment of cottonseed with NH_3 or HCL gas greatly retarded the formation of free fatty acids. Treatment with NH_3 retarded the darkening of the oil and in fact resulted in an oil with a much lighter color than that from the untreated seed. Progress of the hydrolysis of glycerides in the oil in cottonseed can be expressed quantitatively by the use of the differential equation: $dF/dt = k(F)(100-F)$ where F = the percentage free acids; 100-F = percentage unhydrolyzed fat, and k = the rate constant. Three possible mechanisms for the hydrolytic splitting of the glycerides of cottonseed oil are discussed and evaluated on the basis of the kinetics of this reaction.

173. KARON, M. L.
Hygroscopic equilibrium of cottonseed. J. Am. Oil Chemists Soc. 24:56-58, 1947.

Studies on the equilibrium moisture content of cottonseed showed a linear increase from 6.03% to 10.27% moisture content with a relative humidity range from 31% to 71% and a rapid increase from 10.27% to 22.19% with a relative humidity range from 71% to 93%. The hulls contained more moisture than the meats, when separated.

174. KARON, MELVIN L. and HILLERY, BARBARA, E.
Hygroscopic equilibrium of peanuts. J. Am. Oil Chemists' Soc. 26:16-19, 1949.

The hygroscopic equilibria and rates of attainment of hygroscopic equilibrium of freshly dug, naturally cured, and artificially cured peanuts have been determined over the range of 11-93% relative humidity at 25°C. The hygroscopic equilibrium does not appear to be dependent on the method of curing. At a constant relative humidity, the moisture content is lowest in the meats and increasingly greater in hearts, whells, and skins respectively. Since the hygroscopic equilibrium is the same at both 25° and 35°C, it is more advantageous when speed of drying is important to use the higher temperature because equilibrium is attained more rapidly.

175. KARON, M. L. and ADAMS, MABELLE E.
Hygroscopic equilibrium of rice and rice fractions. Cereal Chem. 26(1):1-12, 1949.

An investigation has been made of the rate of sorption and desorption of moisture by rough rice, head rice, bran, polish, and hulls over the range of 11 to 93% relative humidity at 25°C. The hygroscopic equilibrium of these same fractions has been determined over the same relative humidity range. If the relative humidity of the atmosphere at

25°C is raised from 10 to 90% the moisture content of whole rice and its fractions increases as follows: rough rice from 4.4 to 17.6%, polished rice from 5.2 to 18.8% bran from 5.0 to 13.0%, polish from 5.3 to 18.0%, and hulls from 3.7 to 15.3%.

176. KELLER, A. G.
Factors influencing the keeping qualities of raw sugars. Sugar J. 2(6):25-30, 1939.

The effects of moisture and other impurities and of relative humidity during storage on the keeping qualities of sugar are reviewed with 26 references. Sugars are hygroscopic above 50-60% relative humidity, but over the range from 20-30 up to 50-60 mesh particle size had little effect on the rate of moisture absorption. When the sugar is well made and the ratio of moisture to nonsucrose is 0.25 or less, microörganisms are unable to thrive on the sugar.

177. KERTESZ, Z. I., MASSEY, L. M. JR., PARSONS, G. F. and SIMON, MORRIS
Storage behavior of powdered dehydrated cranberries. Food Technol. 17(12):1569-1572, 1963.

Storage stability test measured by sag measurement, were made on jelly from canned dehydrated powdered cranberries of 2.6-8.7% moisture content at 34-131°F. At less than 4% moisture there was little deterioration within one year's storage at 90°F or below. At 100°F there was greater deterioration but after a year the product still made a jelly that did not fall apart. Increase in the moisture content or storage temperature resulted in rapid deterioration. The possible role of changes in cranberry pectin in this storage deterioration was investigated and good correlation was demonstrated between loss in cranberry jelly firmness and the viscosity of pectins extracted. The results indicate that relatively low moisture contents are required to assure extended storage life.

178. KLINE, LEO, GEGG, JOAN E. and SONODA, T. T.
Role of glucose in the storage deterioration of whole egg powder. II. A browning reaction involving glucose and cephalin in dried whole eggs. Food Technol. 5:181-187, 1951.

Evidence is presented for an amine-aldehyde reaction involving glucose and the phospholipid cephalin, which occurs during the storage of dried whole eggs. The removal of glucose before drying eliminates or greatly retards changes normally occurring in the phospholipid fraction during storage. These include loss in amino groups, browning, and development of fluorescence and ultraviolet absorption.

179. KOCH, ROBERT B.
Stable active dry yeast puts fresh bread on overseas menu. Research and Development Associates. Activities Report 5(4):268-271, 1953.

Active dry yeast, because of a short shelf-life, has long been the weak link in the chain of supply of bread ingredients to the overseas bakeries. Because of the importance of fresh bread from the standpoints of morale and nutrition, a comprehensive study of the critical factors affecting the storage stability of active dry yeast was undertaken jointly some time ago by the QMFCI and the active dry yeast manufacturers. The conditions of this study and its results are set forth in the following article. Also discussed are several changes in procedures for handling active dry yeast for breadmaking and also for testing of stability under accelerated storage conditions.

180. KOZMIN, NATALIE P.
The aging of wheat flour and the nature of this process. Cereal Chem. 12:165-171, 1935.

Experiments show that during the storage of flour a change in the quality of gluten in the direction of its strengthening has been observed. The direct cause of this change is the accumulation of free fatty acids caused by a slow process of fat hydrolysis. Removal of fatty acids from the flour rejuvenates it, and addition of free unsaturated fatty acids to fresh flour produces the same effect as natural aging. Flour ages without the participation of oxygen. Temperature is the most important factor influencing aging of flour.

181. KRAYBILL, J. R., DUGAN, L. R., JR. BEADLE, B. W., VIBRANS, F. C., SWARTZ, VeNONA and REZABEK, HELEN
Butylated hydroxyanisole as an antioxidant for animal fats. J. Am. Oil Chemists Soc. 26(9):449-453, 1949.

Butylated hydroxyanisole has been developed as a new and highly effective antioxidant for animal fats. It is readily soluble in fats, and practically insoluble in water. It is very effective in protecting foods made with lard against rancidity. Extensive toxicological tests with rats have failed to demonstrate any physiological effects when the antioxidant is used daily in food.

182. KUPRIANOFF, J.
'Bound water' in foods. In Fundamental Aspects of the Dehydration of Foodstuffs. p.14-23. Society of Chemical Industry, London. 1958.

The role of water in food is described and also the forms in which it may be 'bound'. The possible effects of decreasing water content and

the problem of the reversibility of changes are discussed, and some examples are given of biochemical, biological and technological reversibilities where an optimum water content gives maximum reversibility. Total water content cannot be separated into 'free' and 'bound' water and an explanation is given for this.

The freezing method is suggested as the most accurate procedure for determining 'unfreezable' water, especially when this is related to the protein content of the food and not to its total solids. A summary of recent work is given showing that in protein foods there is an almost stoichiometric relationship between 'unfreezable' water content and protein nitrogen of two molecules of water to one atom of protein nitrogen.

183. KUPRIANOFF, J.
Some factors influencing the reversibility of freeze-drying of foodstuffs, In Freeze-drying of foods; proceedings of a conference p.16-24, Washington, Nat. Res. Council, 1962.

To minimize product damage in the freeze-drying process the following are important. With materials having structure, freeze before starting to withdraw water vapor; if foaming is wanted, freezing should be done under vacuum. Dry at a sufficiently low temperature until all free water is removed. Only then may the temperature be raised carefully. To decrease the denaturation, withdraw water until a concentration of less than 20%, relative to the protein content, is reached. Avoid marked differences in water content in different zones of the product. Store at a water content of not more than 15%; the optimal value must be determined for each item.

184. KVAALE, OSKAR and DALHOFF, EMIL
Determination of the equilibrium relative humidity (ERH) of foods. Food Technol. 17(5):659-661, 1963.

Strips of filter paper were dipped into one of each of saturated solutions of $ZnSO_4$, Na citrate, tartrate, bromate, sulphate, phosphate, $BaCl_2$, KNO_3, $Pb(NO_3)_2$ and dried at room temperature. The ERH of a sample is found by placing it in a sealed unit (Petri dish, the inside of the upper half of which has a series of such test papers, of known ERH) 20h. at 20° and noting the dry and/or wet strips. Results are compared with those found by a graphical interpolation method. The method was developed for measurement of humidities $\geq$90% R.H., e.g., in studies of prepacked meat products. (From J. Sci. Food Agric. 14(12):ii-307).

185. LANDMANN, W. A.
Role of water and oxygen in the deterioration of freeze-dried meat. American Meat Institute Foundation, Chicago, report no.8, final (Contract DA-19-129-QM-1333). 82p. 1961.

Production of freeze-dried fresh and cooked meat at various moisture levels, methods for studying deteriorative changes on storage, and results of analyses are reported. Statistical treatment of data shows moisture and temperature cause greatest deteriorative changes. Oxygen level has little or no effect.

186. LANDROCK, ARTHUR H. and PROCTER, BERNARD E.
Measuring humidity equilibria. Mod. Packaging 24(6):123-130, 186. 1951.

A technique has been devised for measuring the equilibrium relative humidities of food products. The three methods now in common use - the manometric method, the electric hygrometer method, and the weight equilibrium method - are given in brief outline. The new technique is based on the observation that under constant conditions of weight, surface area and moisture content of product, temperature of environment and duration of test period, the gains or losses in weight of a product are proportional to the relative humidity of the test atmosphere. By plotting these gains and losses graphically with reference to the relative humidity and drawing a curve through the plotted points, the equilibrium relative humidity can be read from the point where the curve intersects the line of no gain or loss in weight. This technique will give accurate results in period from a little over one hour to two days.

187. LANDROCK, ARTHUR H. and PROCTER, BERNARD E.
A new graphical interpolation method of obtaining humidity equilibria data, with special reference to its role in food packaging studies, Food Technol. 5:332-337, 1951.

A method is described for determining equilibrium relative humidities of a wide variety of products rapidly and with simple equipment. All factors involved in the determination are held constant except relative humidity. Samples of a product of a certain moisture content are exposed to different relative humidities for an arbitrary constant time, usually one hour. Each sample is then weighed once only, in contrast to the usual methods whereby repeated weighings are made until weight equilibrium is reached. The gains and losses in weight per unit of time are plotted with reference to relative humidity. By interpolation, the equilibrium relative humidity is read at that point where the smooth curve drawn through the plotted data intersects the baseline representing

no weight change. Repetition of this procedure with other samples of other moisture contents gives data for a humidity-moisture equilibrium curve covering a wide range of relative humidities and equilibrium moisture contents. Approximately two days are necessary to secure this curve.

188. LEA, C. H.
Chemical changes in the preparation and storage of dehydrated foods. In Fundamental aspects of the dehydration of foodstuffs. p.178-196. Soc. Chem. Ind., London, 1958.

Primarily a discussion of browning-type reactions and lipid oxidations. In the various investigations reviewed, freeze-dried milk, beef, fish were among the foodstuffs that were studied. (From Nat. Agric. Lib., Library list no. 77, 1963)

189. _____
Dried meat. V. The storage of dried meat. J. Soc. Chem. Ind. T62, 200-205, 1943.

The effects of atmospheric oxygen and of moisture content on the keeping properties of vacuum-ice-dried and of air-dried meat have been investigated, both at normal and at tropical temperatures. While most samples of dried beef and mutton and some samples of pork have a storage life of a few months in a non-airtight container, it is shown that for optimum keeping properties the meat should be compressed (or gas-packed) in an airtight container. Under such conditions dried beef, mutton, and pork have been kept in good condition at 68°F for periods considerably in excess of one year.

190. LEA, C. H. and HANNAN, R. S.
Studies of the reaction between proteins and reducing sugars in the "dry" state. I. The effect of activity of water, of pH and of temperature on the primary reaction between casein and glucose. Biochim. et Biophys. Acta 3:313-325, 1949.

The reaction between casein and glucose (one molecule per free amino group of the casein) in the "dry" state has been studied by determination of free amino-N and measurement of changes in colour.

The rate of loss of amino-N has been found to depend on the following factors: a) It is powerfully influenced by the activity of water in the system, showing a maximum at water contents corresponding approximately to 65 or 70% relative humidity, and falling away to low values at very high and very low water contents. This relationship has been found to apply at 37, 70 and 90°C. b) It increases with pH from low values at pH 3 up to pH 8 at least, and probably up to pH 10.

c) It shows a progressive increase with temperature from 0 to 90°C and, when the relative humidity is kept constant at 70%, conforms to the Arrhenius equation with a Q_{10} 15-25°Cof 5.4.

The development of color increases with increase of water content, pH and temperature.

Possible mechanisms relating the effects of water to the multilayer adsorption theory of Brunauer, Emmett, and Teller are discussed.

191. LEGAULT, R. R., MAKOWER, B. and TALBURT, W. F. Apparatus for the measurement of vapor pressure. Anal. Chem. 20: 428-430, 1948.

A complete description and directions for making, filling, calibrating, and operating an apparatus for the det rmination of the vapor pressure of dehydrated agricultural products are given. The vapor pressure is observed by means of a Dubrovin type manometer which has a sensitivity about 7 times that of the usual U-tube Hg manometer. The precision and accuracy of the observations are estimated to be about ± 0.04 mm. and ± 0.08 mm., respectively.

192. _____, HENDEL, CARL E., TALBURT, WILLIAM F. and POOL, MORRIS F. Browning of dehydrated sulfited vegetables during storage. Food Technol. 5:417-423, 1951.

Correlation has been made of the effects of moisture content, sulfite, package atmosphere, and storage temperature on browning of dehydrated white potato, carrot, and cabbage. Substantial protection against browning is afforded by low moisture and also by sulfite. Decrease in rate of browning per 2% decrease in moisture content was found to vary from 1.2- to 4.6-fold, depending on kind of vegetable and moisture content. The moisture effect increased as the product approached complete dryness. Rates of browning increased 6- to 8-fold per 18°F (10°C) rise in temperature. There was little difference in rate of browning of air- and nitrogen-packed samples.

193. _____, TALBURT, WILLIAM F., MYLNE, ANN M., and BRYAN, LOUISE A. Browning of dehydrated vegetables during storage. Ind. Eng. Chem. 39:1294-1299, 1947.

The rate of nonenzymatic browning of dehydrated vegetables has been studied as a function of temperature, moisture content, and confining atmosphere. The browning proceeds in linear fashion up to, and for a reasonable distance beyond, the limit of palatability for dehydrated nonsulfited carrot, white potato, onion, and sweet potato. The effect of oxygen on the browning rates of these four dehydrated vegetables is relatively small. The browning rates vary exponentially

with the reciprocal of the absolute temperature. The temperature coefficients are high, the Q_{10} values varying from 5.0 to 8.4 among these four vegetables. The browning rates vary exponentially with the moisture content over the range studied.

194. LEGAULT, R. R., HENDEL, C. E. and TALBURT, W. F.
Retention of quality in dehydrated vegetables through in-package desiccation. Food Technol. 8(3):143-149, 1954.

A comprehensive study of the effect of in-package desiccation on the storage stability of dehydrated white potato, sweet potato, cabbage, beet, and onion is reported. It was demonstrated that substantial protection against nonenzymatic browning can be obtained by the in-package desiccation of these products. The losses of ascorbic acid and of sulfite were also markedly reduced. Oxygen absorption was reduced at 120°F (49°C) but was accelerated at 75°F (24°C). Packed in air, accelerated oxidative changes (fading and off-flavor development) were observed with sweet potato but not in this test with the other vegetables, thus suggesting that for some products, nitrogen- or vacuum-packing may prove desirable in conjunction with in-package desiccation. Since the temperature coefficient of desiccation (2- to 3-fold per 18°F or 10°C) is much lower than that of browning (5- to 8-fold per 18°F), best protection from in-package desiccation will result if the packaged product is held at moderate temperature until a substantial part of the desiccation has occurred.

195. _____, HENDEL, CARL E., TALBURT, WILLIAM F. and RASMUSSEN, LOIS B.
Sulfite disappearance in dehydrated vegetables during storage. Ind. Eng. Chem. 41:1447-1451, 1949.

Sulfite disappearance in dehydrated sulfited carrot, white potato, and cabbage stored at temperatures ranging from 24° to 49°C. proceeds approximately as a first-order reaction. The apparent activation energies, calculated according to the Arrhenius equation, are high, ranging from 33 to 43 kg.-cal. The rate increases markedly as the moisture content is raised; for carrot and white potato at 38°C., the increases are about 3-and 5-fold, respectively, over the moisture ranges of 5.4 to 8.0, and 5.3 to 9.2%. For sulfited vegetables stored in air as compared to similar samples stored in nitrogen, the respective rates of sulfite disappearance are in the ratio of about 1 to 1 at 49°C., and 2 to 1 at 24°C. Little change in the sulfite disappearance rate in dehydrated carrot is caused by varying the blanching time from 2 to 8 minutes, by sulfite application during or after blanching, or by application of the sulfite from solution or from gas. On the basis of the generalizations presented herewith, it is feasible to estimate the life expectancy of the sulfite in other samples of dehydrated sulfited vegetables.

196. LEITCH, JAMES MUIL AND RHODES, DOUGLAS N.
Recent advances in food science - 3: biochemistry and biophysics in food research. London, Butterworths, 325p., 1963.

Individual papers pertaining to moisture in food and other aspects are listed under their author.

197. LEWIS, V. M., ESSELEN, W. B. JR. and FELLERS, C. R.
Nitrogen-free carboxylic acids in the browning reaction. Ind. Eng. Chem. 41(11):2591-2594, 1949.

The reaction between nitrogen-free carboxylic acids and glucose may be a cause of browning in foodstuffs. This reaction may be similar in nature to the Maillard reaction, but because the nitrogen-free acids are more abundant in foodstuffs than the amino acids, their importance in the browning reaction should not be overlooked.

198. LIVINGSTON, H. K.
Cross-sectional areas of molecules adsorbed on solid surfaces. J. Am. Chem. Soc. 66:569-573, 1944.

For four different finely-divided solids, adsorption isotherms have been measured both by the Brunauer-Emmett low temperature nitrogen adsorption technique and by the McBain-Bakr method, using vapors from substances which boil well above room temperature. By comparison of the various isotherms, the cross-sectional area values for the adsorbed molecules (in $Å^2$ per molecule) have been found to be H_2O, 10.6; PrOH, 20.0; heptane, 55.0, if nitrogen is taken to be 15.4. These areas are in every case in good agreement with the molecular areas as determined from density, X-ray, or film balance measurements. The modified McBain-Bakr technique offers a method for measuring the section areas of adsorbed organic molecules of all types. It can also be used for determining the surface area of finely-divided solids from adsorption measurements at room temperature, using the vapors from ordinary volatile liquids.

199. LOVEN, A. W. and VERMILLION, F. J.
Adsorption - desorption properties of sorbents. West Virginia Pulp and Paper Co., Charleston, S. C. Bimonthly progress rept. No. 3, 19 Mar - 18 May 64. 24p. (Contract DA 18 035AMC106(A)) 1964.

Adsorption and desorption isotherms of nitrogen at 77.7K are reported for an activated viscose carbon fiber felt. The surface area is comparable to that of a previously studied activated carbon fiber made from Fortisan, but higher than that of a sample of coal base granular carbon, also previously studied. Pore distribution analysis shows that the viscose felt has much less volume in pores in

the 40-1000A radius range than the others. Adsorption and desorption isotherms of dimethyl methylphosphorate, DMMP, are reported for 25°C for all three sorbents mentioned and for 35°C for the viscose felt. Total micropore volumes determined from the nitrogen and DMMP isotherms are reported for the three sorbents discussed. Smaller values are obtained with DMMP in all cases suggesting that the screening of DMMP from certain pores, accessible to the smaller nitrogen molecule, is taking place. Apparatus for the measurement of rates of adsorption and desorption at constant pressure is described. It is based on the Cahn electrobalance. Diffraction measurements on the Fortisan carbon fiber indicate that it is essentially amorphous to X-rays. An oxygen surface group determination is reported for the Fortisan carbon felt.

200. McBAIN, J. W. and BAKR, A. M.
A new sorption balance. J. Am. Chem. Soc. 48:690-695, 1926.

A new sorption balance is described which, by using a spring made of fine silica fiber, permits measurement of the sorption of gases and vapors on solid surfaces over a wide range of experimental conditions of temperature without exposing the sample to any foreign vapor.

201. McCalla, A. G., McCAIG, J. D. and PAUL, A. D.
Effect of various conditions of storage on baking quality of flour. Can. J. Research 17C:452-459, 1939.

Flour stored in sealers in a refrigerator at 2°C did not change in quality for 22 months after milling. Similar flours stored in sealers at room temperature deteriorated significantly within three months, while a third lot stored in small bags at room temperature showed first a definite improvement and then rapid deterioration. At the end of 22 months flours stored in sacks were much the poorest. Acidity of all flours increased with storage, but this determination was of little value in estimating flour quality.

202. McCOMB, ELIZABETH A. and WRIGHT, HENRY M.
Application of formamide as an extraction solvent with Karl Fischer reagent for the determination of moisture in some food products. Food Technol. 8:73-75, 1954.

Formamide was investigated as an extraction solvent for use with Karl Fischer reagent for the determination of moisture in beans, cake mix, dried whole eggs, egg noodles, rolled oats, potato starch, rice, wheat, and garlic, onion, orange, and tomato powders. Formamide was found to be more versatile than methanol, the commonly used extraction solvent. The results obtained are reported and compared with those determined by vacuum-oven methods.

203. McILRATH, WAYNE J.
Investigations of physiological aspects of plant water relations. University of Chicago, Report No. 14, Final, 29 March 1957 - 31 August 1960, (Contract DA 19-129-QM-915), 104p., 1960.

Experimental work is reported on (1) Biological dehydration in seeds and (2) Rehydration characteristics of dried Swiss chard leaf tissue.

204. _____, WAYNE, J., DRUMKE, J. S. and BELL, W. D.
Investigations of plant water relations of selected food crops as affected by various physiological conditions. Univ. of Chicago, Report No. 7, Final, 31p. 1 September 1960 - 28 February 1962 (Contract DA 19-129-QM-1608) 1962.

Experimental work is reported on: (1) Physical factors influencing rehydration of bean fruits, (2) Influence of soil fertility, light intensity and moisture stress on rehydration of resulting fruits, (3) Tissue age and rehydration.

205. MacKINNEY, G., LUKTON, A. and GREENBAUM, LEONA
Carotenoid stability in stored dehydrated carrots. Food Technol. 12(3):164-166, 1958.

Data are presented which show that in the absence of molecular oxygen, the carotenoids of dehydrated carrots and -carotene in a glucose-glycine synthetic mixture are unaffected by severe browning.

206. McLAREN, A. D. and ROWEN, JOHN W.
Sorption of water vapor by proteins and polymers: J. Polymer Sci. 7(2/3):289-324, 1951.

A review of the methods of measuring sorption of water vapor by proteins and polymers and a discussion of the theories of the process including the thermodynamic considerations, is presented.

207. MAKOWER, BENJAMIN
Determination of water in some dehydrated foods. Advances in Chemistry Series No. 3, Analytical methods in the food industry. Amer. Chem. Soc. pp.37-54, 1950.

Direct or indirect methods may be used to determine moisture in dehydrated foods. Indirect methods must be calibrated in terms of direct methods - the most common of which are the oven, distillation, and Fischer methods. Accuracy of the direct methods is difficult to evaluate except by comparison with a chosen reference method. Several reference methods are reviewed, but none can be given an unqualified

recommendation as most practical and suitable for all foods. An indirect measure of moisture is the equilibrium vapor pressure of water, which can be measured easily and accurately. Arguments are presented to show that vapor pressure may be a better index of the stability of dehydrated foods than the moisture content, which has been frequently used for this purpose.

208. MAKOWER, BENJAMIN and DYE, WALTER B.
Equilibrium moisture content and crystallization of amorphous sucrose and glucose. J.Agr. Food Chem. 4(1):72-77, 1956.

Amorphous (metastable) sucrose and glucose powders were exposed to relative humidities ranging from 4.6 to 33.6% at 25°C. At humidities lower than about 12% for sucrose and 5% for glucose, moisture equilibrium was attained and practically no crystallization occurred in nearly 3 years. A vapor pressure isotherm was evaluated for sucrose-water solutions from 0 to 100 % sucrose at 25°C. At higher humidities the absorbed water initiated crystallization of the sugars with subsequent release of moisture to yield essentially anhydrous materials. The rate of crystallization of amorphous sucrose, evaluated from changes in the moisture content, followed an exponential law with respect to time, after an initial induction period. This period was interpreted to be the time for a build-up of sufficient nuclei to initiate an appreciable rate of crystallization.

209. MAKOWER, BENJAMIN and DEHORITY, G. L.
Equilibrium moisture content of dehydrated vegetables. Ind. Eng. Chem. 35:193-197, 1943.

The equilibrium moisture content of some dehydrated vegetables was determined by allowing them to attain equilibrium in air-free desiccators containing sulfuric acid solutions to control the relative humidity. Fresh vegetables were used for desorption measurements and dried vegetables for adsorption. Experiments were carried out on carrots, cabbage, yams, spinach, and white potatoes. The sorption isotherms for all the vegetables are S-shaped and are characterized by an inflection point in the neighborhood of 5 percent moisture content.

Measurements were also made on blanched white potatoes. Blanching causes a decrease in the equilibrium moisture content. The decrease is ascribed to a change in the physical state of the starch granules in the potato.

Application of the sorption data to dehydration and packaging of vegetables is briefly discussed.

210. MAKOWER, BENJAMIN, CHASTAIN, SARAH MYERS, and NIELSEN, ELISABETH
Moisture determination in dehydrated vegetables. Vacuum oven method. Ind. Eng. Chem. 38(7):725-731, 1946.

The loss of weight that occurs when dehydrated potatoes, carrots, cabbage, and onions are heated in a vacuum oven has been studied as a function of time, temperature, fineness of grinding of the sample, and degree of evacuation in the oven. The loss due to thermal decomposition of the vegetables has been estimated, and the combined results have been used to establish conditions for the determination of moisture in the four vegetables.

211. _____ and MYERS, SARAH
A new method for the determination of moisture in dehydrated vegetables. Proc. Inst. Food Technol.156-164, 1943.

The standard method of determining the moisture content of dehydrated vegetables, the vacuum-oven method, is described and evaluated. It is concluded that the vacuum-oven method does not give a satisfactory measure of the true moisture content of the material. A proposed new method is based on the principle that a given vegetable material when placed in an atmosphere of a definite relative humidity will have, at equilibrium, a definite moisture content. That is, a material of a definite moisture content has a definite water-vapor pressure at a definite temperature. This pressure can be readily measured on an ordinary oil manometer and thus be used as a measure of the moisture content. The method of measuring vapor pressure is described and evaluated.

212. MAKOWER, BENJAMIN and NIELSEN, ELISABETH
Use of lyophilization in determination of moisture content of dehydrated vegetables. Anal. Chem. 20:856-858, 1948.

A new reference method for the determination of moisture content of dehydrated vegetables involves addition of a large amount of water to a weighed sample of vegetable; freezing and drying in the frozen state (lyophilization); and completion of the drying in a vacuum oven or vacuum desiccator in the presence of an efficient water adsorbent. The last step can be completed in a relatively short time at, or slightly above, room temperature, because of a marked increase in drying rate brought about by lyophilization. Data presented for white and sweet potatoes, beets, and carrots show that the lyophilized materials can be dried unambiguously to constant weight and that the loss in weight may be taken as a measure of the moisture content. As the final dry weight is virtually independent, within wide limits, of the temperature of drying, the new method obviates the necessity of careful control of drying temperature.

213. MAKOWER, BENJAMIN
Vapor pressure of water adsorbed on dehydrated eggs. Ind. Eng. Chem. 37: 1018-1022, 1945.

Equilibrium pressure of water vapor over spray-dried whole eggs was determined at six temperatures varying from 17.1° to 70°C. and at moisture contents ranging from 0.5 to 5.5%. The results agreed well with similar data on eggs dried from the frozen state and with the less extensive data published by Gane. The results were analyzed by a graphical method suggested by Othmer, and from this analysis was derived the isosteric heat of adsorption of water on dried eggs at various moisture levels. The ratio of the isosteric heat to the latent heat of condensation of water vapor increases from 1.1 to 2.1 as the moisture content decreases from 5.5 to 0.5%. It was also shown that the adsorption isotherms can be represented, within certain limits, by the Brunauer, Emmett, and Teller theory of adsorption of gases on solids.

214. MALLETTE, M. F., DAWSON, C. R., NELSON, W. L. and GORTNER, W. A.
Commercially dehydrated vegetables. Oxidative enzymes, vitamin content, and other factors. Ind. Eng. Chem. 38:437-441, 1946.

Commercially dehydrated cabbage, Irish potatoes, and sweet potatoes were stored for one year under controlled conditions of temperature, moisture and atmosphere. The fresh, blanched, and dehydrated samples were assayed for vitamin, oxidative enzyme, available iron, total copper, and moisture content. Similar analyses on the dehydrated samples were made several times during the storage period. The dehydrated cabbage and potato deteriorated rapidly as evidenced by loss of ascorbic acid, discoloration, and development of off-odor when stored above 70-80°F and at moisture levels above 7% in the case of the white potato. At lower storage temperatures the products were more stable. No correlation between this deterioration and the oxidative enzyme content or iron and copper content of the dehydrated vegetables was found. All the vitamins assayed except ascorbic acid were fairly stable during storage. The use of sulfite in the blanch reduced the ascorbic acid losses in the dehydrated cabbage during storage. However, thiamine was destroyed by the sulfite. There was no evidence of any significant amount of oxidative enzyme regeneration during the storage period. The data do not support the view that the storage deterioration of commercially dehydrated cabbage and potatoes may be due to the action of oxidative enzymes whose presence might arixe from inadequate b anching or regeneration during storage.

215. MARTEM'YANOVA, K. B.
Opytnoe khranenie ryby vysushenoi metodom sublimatsii. (Experimental storage of fish dried by the freeze-drying method). In Makarova, T. I., ed. (Tekhnologiya Rybnykh Produktov) Selected articles from technology of fish processing, p.161-169. Moscow, Pishchepromizdat, 1958.

Describes results of numerous experiments made studying storage behavior of freeze-dried fish. Observations are recorded about changes in taste, texture, and proteins. Different packaging methods and storage conditions are reviewed. Several tables accompany the article. (From Nat. Agric. Lib., Library list no. 77, 1963.)

216. MATHESON, N. A.
Absorption of atmospheric moisture by freeze-dried pork and fish. Nature 184(4703):1949-1950, 1959.

Results of this investigation emphasize the importance, with regard to storage life, of preventing dried foodstuffs from picking up much moisture. (From Nat. Agric. Lib., Library list no. 77, 1963)

217. MATHESON, N. A.
Enzymic activity at low moisture levels and its relation to deterioration in freeze-dried foods. J. Sci. Food Agr. 13(4):248-254, 1962.

Loss of glycogen occurred in two different model systems containing enzymes from meat, when they were stored at humidities comparable to those of freeze-dried foods. The losses were much greater in experimental samples than in controls in which the meat extract was either boiled or absent. The fall in glycogen is attributed to enzyme activity which seems to persist at 3% moisture content and perhaps even lower. Enzymic activity at such moisture levels could explain the sensitivity of raw freeze-dried foodstuffs to moisture level during storage and the insensitivity of precooked freeze-dried products.

218. MATHESON, N A. and PENNY, I. F.
Storage of dehydrated cod. Food Process. Packaging 30(354):87-91; 98; 30(355):123-127, 1961.

Describes two storage tests with fish dehydrated by vacuum contact-plate drying process, and one test with AFD cod steaks. The effect of moisture content, temperature, and packing atmosphere was observed. A taste panel evaluated the food samples. (From Nat. Agric. Lib., Library list no. 77, 1963)

219. MELLON, EDWARD F. and HOOVER, SAM R.
Hygroscopicity of amino acids and its relationship to the vapor phase water absorption of proteins. J. Am. Chem. Soc. 73:3879-3882, August 1951.

The marked influence of the polar groups upon the vapor phase water absorption of proteins has led to a study of the water absorption of these same polar groups in a number of model substances. In this manner the influence of interactions between polar groups upon the water absorption phenomena could be studied. This paper reports the water absorption results obtained for the amino acids and a number of peptides and other amino acid derivatives. The results indicate that under conditions where the polar groups can be expected to be very highly coordinated into the crystal structure, they absorb little if any water even at high humidities. However, all types of water absorption phenomena, including hysteresis, were shown to be possible within these relatively simple substances. The evidence presented indicates that the polar groups of the proteins must be comparatively uncoordinated and completely available to water molecules. This is a situation similar to that required by the polarization theory of adsorption and, therefore, it is not surprising to find that the polarization theory isotherm describes the water absorption curve of proteins from 6 to 93% relative humidity.

220. MELLON, EDWARD F., KORN, ALFRED H. and HOOVER, SAM R.
Water absorption of proteins. I. The effect of free amino groups in casein. J. Am. Chem. Soc. 69:827-831, 1947.

A series of benzoylated caseins has been prepared with varying amounts of free amino groups. Water-absorption studies on these samples have made it possible to distinguish between water absorbed on amino groups and water absorbed on the remaining groups of casein.

The first step in the binding of water by the amino groups of casein seems to be a sharing of one molecule of water between two amino groups below 6 % relative humidity. The B.E.T. treatment of the data, however, indicates a monolayer of one water molecule per amino group.

The second step is a linear increase in absorbed water with increase in relative humidity. Equations are presented for this increase between 0 and 60% relative humidity.

The third step is a rapidly increasing amount of absorption with increase of relative humidity and appears to be a condensation of water on water molecules already attached to the amino groups.

From 24 to 33% (depending on the relative humidity) of the water absorbed by casein is absorbed by the amino groups.

221. MELLON, EDWARD F., KORN, ALFRED H. and HOOVER, SAM R. Water absorption of proteins. II. Lack of dependence of hysteresis in casein on free amino groups. J. Am. Chem. Soc. 70:1144-1146, 1948.

Desorption isotherms have been obtained for a number of benzoylated casein samples with various amounts of free amino acid groups. A definite hysteresis in the sorption phenomena of about one-half the absorption value at 6% R.H. and about one-fifth at 50% R.H. was observed. The hysteresis was independent of the content of free amino groups in the samples, although the amino group is responsible for one-fourth the water absorption in casein. The hysteresis appears to be of two types: a constant hysteresis independent of the humidity from which desorption was started, and a hysteresis proportional to the amount absorbed and due only to absorption above the upper break in the absorption curve. This appears to be the first demonstration of the two-fold nature of the hysteresis phenomena.

222. MELLON, EDWARD F., KORN, ALFRED H. and HOOVER, SAM R. Water absorption of proteins. III. Contribution of the peptide group. J. Am. Chem. Soc. 70:3040-3044, 1948.

The vapor-phase water absorption of glycine peptides from two to six units in length has been determined, and the values show clearly that non-hygroscopic amino acids may give hygroscopic peptides. Polyglycine peptides of longer chain length show that the peptide linkage must be responsible for most of the water absorption by these materials. Comparison of the absorption of the polyglycine peptides with the absorption of proteins indicates that the absorption of the peptide chain backbone is probably of the same magnitude, if not identical, for all long-chain polypeptides and proteins. Peptide groups appear to be responsible for about 45% of the vapor-phase water absorption by casein and 70% of the absorption by zein at 60% relative humidity. A new absorption isotherm for the high humidity range has been presented which permits a linear interpolation between 30 and 80% relative humidity for all proteins and a further linear extrapolation to 100% relative humidity in a few special cases.

223. MELLON, EDWARD F., KORN, ALFRED H. and HOOVER, SAM R. Water absorption of proteins. IV. Effect of physical structure. J. Am. Chem. Soc. 71:2761-2764, 1949.

Sorption isotherms have been measured on a series of wool, silk fibroin and ovalbumin fibers treated to alter the internal physical structure. The severe treatments of these three typical proteins, which alter the internal structure as much as appears possible, have

little effect on sorption of water. The concept that sorption is primarily related to the number of specific sorptive groups present appears to be applicable to proteins, probably because of the heterogenity of the side chains present.

224. MELLON, EDWARD F., KORN, ALFRED H., KOKES, ELSIE L. and HOOVER, SAM R.
Water absorption of proteins. VI. Effect of guanidino groups in casein. J. Am. Chem. Soc. 73:1870-1871, 1951.

The vapor phase water absorption isotherms of the amino groups in casein and of the peptide groups of some long polyglycine molecules show that these polar groups are specific sorptive sites over the entire range of relative humidities. Several casein derivatives containing various amounts of substituted guanidino groups were prepared. The vapor phase water absorption of these samples was not significantly different from the absorption of the free amino groups themselves. The almost constant fractions of the total water absorption at all relative humidities which have been found to be due to the amino, peptide and guanidino groups show that these polar groups, which comprise only a few percent of the total protein, must be considered in any theoretical analysis of the sorption phenomena.

225. MELLOR, J. D.
Vapour phase conditions in freeze-drying. 1961 Transactions of the Eighth Vacuum Symposium and Second International Congress. Pergamon Press, Oxford; New York, p.1064-1068, 1962.

In freeze-drying processes, the rate of drying is limited primarily by resistance to vapour flow from the material and through the space surrounding it, and only to a smaller extent by restrictions on the rate of heat input. Heating the material through the drying surface layers results in faster drying than when heat is effected by conduction through the frozen layer, because of an increase in the molecular motion of the vapour, which is superheated. Rates of drying are obtained from the theory of water vapour transfer for this situation and compared with known rates of freeze-drying, and are discussed in connection with improvements in heat and vapour transfer.

226. MIERS, JACKSON C., WONG, FRANCIS F., HARRIS, JEAN G. and DIETRICH, WILLIAM C.
Factors affecting storage stability of spray-dried tomato powder. Food Technol. 12(10):542-548, 1958.

The data show that spray-dried tomato powder can be stored for 12 months at 100°F when the powder is packed with a desiccant and canned in an inert atmosphere. Under such conditions, production of off-flavors, loss in ascorbic acid or sulfite, and change in soluble color were insignificant.

High moisture levels, presence of O_2, and storage temperatures of 90°F or higher were factors found to be detrimental to storage stability. Thus, if O_2 were eliminated from the can atmosphere by replacing with an inert gas, a moisture content of 1.8% (and perhaps higher) could be tolerated at 70°F for long periods of time. In contrast, at the higher temperatures of 90° and 100°F., it was necessary to reduce the moisture content with an in-package desiccant, as well as to pack in an inert atmosphere in order to get reasonable storage stability in respect to flavor, soluble color, and ascorbic acid retention.

227. MILNER, MAX and GEDDES, W. F.
Grain storage studies. III. The relation between moisture content, mold growth, and respiration of soybeans. Cereal Chem. 23:225-247, 1946.

The respiratory characteristics of soybeans of varying grade were determined at various moisture levels by a method which provided for the simultaneous measurement of oxygen consumption and carbon dioxide production under conditions of continuous and controlled aeration at constant temperature. After time periods of up to 15 days, the seeds were examined to determine the extent of mold growth and chemical deterioration. At moisture levels below 14%, only seed respiration was involved; from 14% up, respiratory increases due to mold growth occurred. At moisture levels where molds proliferated, drastic chemical changes occurred, approximately proportional to the moisture content and the extent of mold growth. Aspergillus glaucus and A. flavus were the principal microflora which proliferated on soybeans in the moisture range studied. Relative humidity rather than actual moisture content of seeds determines their susceptibility to molding.

228. MILNER, MAX and GEDDES, W. F.
Respiration and heating. In Storage of cereal grains and their products, ed. by J. A. Anderson and A. W. Alcock, pp.152-220. Am. Assoc. Cereal Chemists: St. Paul, Minnesota, 1954.

The aerobic and anaerobic respiratory processes and methods of measurement of respiration in seeds are described in detail. The factors influencing the respiration of seeds such as, moisture, temperature, type of microflora, aeration, length of storage, prior history of the seed, and seed variety are evaluated. The effect of chemical treatment on respiration to increase the storage life of

damp grain is discussed. However, since deleterious changes occur in spite of this treatment, it is not yet recommended as a practical measure. Biochemical changes and factors influencing seed viability are briefly discussed. The causes of spontaneous heating and apparatus for its measurement are described. The relationship of laboratory findings to commercial grain storage problems is given.

229. MITCHELL, J. H.
Control of changes occurring in beef during dehydration and subsequent storage. Research and Development Assoc., Food and Container Inst., Activities Report 5(4):296, 1954.

Findings seem to indicate that storage under nitrogen and at low temperatures might lessen fat changes due to oxidation. (From Nat. Agric. Lib., Library list no. 77, 1963)

230. MITCHELL, J. H. and ENRIGHT, J. J.
Effect of low moisture levels on the thermostability of active dry yeast. Food Technol. 11(7):359-362, 1957.

Evidence is presented showing that active dry yeasts with moisture levels of 5.5, 4.0, and 2.2% are more thermostable than the regular commercial ADY of about 8.0%. These lower moisture levels improve the stability by factors of 4, 8 and 17, respectively. Vapor rehydration of the dried yeasts to 8.0 to 10.0% moisture was necessary before they performed efficiently in the regular bread production process.

Vapor pretreatment of the bone-dry yeasts did not reactivate them for satisfactory performance in dough preparation.

In-package desiccation was an effective method of reducing the moisture content of commercial ADY to lower levels.

231. MORAN, T.
Lipase in oats. Food Manuf. 27:73-74, 1952.

The most serious deterioration that occurs in oatmeal products is caused by the action of the enzyme lipase on the fat content which results in the production of free fatty acid and glycerol. Investigations have been carried out at the Research Station of the Association of British Flour-Millers to study this and many other problems connected with oats and oat products.

232. MORRIS, HERMAN J. and WOOD, ELIZABETH R.
Influence of moisture content on keeping quality of dry beans. Food Technol. 10(5):225-229, 1956.

Moisture content of dry beans is a most important factor influencing

their stability. Above 13% moisture beans deteriorate in flavor and texture significantly in 6 months at 77°F. In 12 months they become very unpalatable in flavor and texture and in most instances increase significantly in lipid acid value. A lipid acid value of 20 or more indicates low organoleptic quality.

Losses in catalase and phosphatase activities are not correlated as well with losses in quality as are changes in lipid acid value.

Beans below 10% moisture maintained their quality for two years at 77°F almost as well as control samples stored at -10°F.

233. MORRIS, H. J., OLSON, R. L. and BEAN, R. C.
Processing quality of varieties and strains of dry beans. Food Technol. 4:247-251, 1950.

A brief review of the literature on hardshell beans is followed by the experimental results on 12 samples representing 4 varieties of beans. The factors studied were rates of water imbibition, percentages of hardshell beans in samples, effect of hot water treatment on hardshell beans, cooking and processing qualities. The effect of different relative humdities on equilibrium moisture content was determined for one sample.

234. MORSE, R. E.
Preparation and storage stability characteristics of dehydrated sausage products. Rutgers U., New Brunswick, N. J. Report No. 7 (Final) (Contract DA 19-129-QM-1118), 15p, 1962.

Freeze-dried sausages were tested for seven months regarding the following factors: Storage temperature, moisture content, salt level, antioxidant level, and length of storage period. (From Nat. Agric. Lib., Library list no. 77, 1963.)

235. MORSE, ROY E. and FELLERS, CARL R.
Storage studies on active dried bakers' yeast. Food Technol. 3:234-236, 1949.

Active dried yeast first appeared in quantity during World War II; 6,000 tons were produced in 1945. Storage conditions for this yeast were not widely known. Storage tests in sealed containers containing air, oxygen, nitrogen, CO_2, and partial vacuum, stored at various temperatures ranging from -20°C to 37°C were carried out. The reaction of yeast exposed to sunlight was also tried. Results showed that temperature had the greatest influence on shelf-life of active dried yeast. Light, packaging material and atmosphere appeared

to have little effect. Oyaas, Johnson, Peterson and Irvin found no difference among samples stored in CO_2, nitrogen, or in vacuum, but deterioration was most rapid in air and was dependent on the amount of air and method of manufacturing. Preliminary investigations by the authors point strongly to the importance of the humidity of the packaging atmosphere.

236. MOSSEL, D. A. A. and REITH, J. R.
Entrainment of distillation as a reference method for the determination of water content of foods. II. Development of a convenient method of entrainment distillation. Rec. Trav. Chim. 70:297-312, 1951.

After cleaning the apparatus, exact dimensions of which are detailed in chromic acid solution (equal parts of 10% $K_2Cr_2O_7$ solution and 96% H_2SO_4) and drying at 130°, put 1.2g pumice stones 2 mm. in diameter into the 150-ml. distillation flask, to prevent bumping, add enough sample to yield 1.8ml. water, and 60ml. of isooctane. Fill the Bidwell-Sterling-type receiver (C.A. 19, 620) with the solvent and connect the condenser equipped with a control trap tube. Heat the flask in an oil bath at 163 $\pm$ 2° and keep the cooling water running at a rate sufficient to keep the condensation ring at less than 3 cm. above the joint. Continue the distillation for 5 hours. Use a defatted Cu wire to work down any water droplets. Continue distillation 0.5 hours after removal of the Cu wire or until 2 consecutive readings do not differ by more than 0.005 ml. When S is weight of sample in g., V is volume of final reading in ml. and c is weight increase of control tube in g., then the water content of the sample in percent is (V + 0.03 +c) X 100/S. Creeping can be prevented by the use of 2 glass wool mats placed in a vertical tube connecting the still and receiver. The apparatus was calibrated by using $BaCl_2 2H_2O$. Cyclohexane, b. 80°, was also used as the entrainer.

237. _____, MOSSEL-HENS, H. A. M. and REITH, J. R.
Entrainment distillation as a reference method for the determination of water content of foods. Rec. Trav. Chim. 70:331-343, 1951. III. Application of the method developed to some model substrata.

The water content of glucose hydrate, $C_6H_{12}O_6H_2O$, lactose hydrate (α-lactose), levulose mixtures., potato starch, casein, wheat bran, powdered bread, full-fat soybean flour, and Madagascar cloves was determined by entrainment distillation with isooctane, and compared with vacuum desiccation at 75° over P_2O_5 and $<$1mm. Hg, and with the same desiccant and vacuum at room temperature. The results in general were in agreement. The entrainment distillation method was faster and had greater applicability since samples rich in lipids and essential

oils caused no difficulties. However, lactose hydrate took about 40 hours per determination by the distillation method (the other methods taking 4 days to 2 weeks) and mixtures containing levulose and sucrose must be neutralized otherwise high results are obtained.

238. MOSSELL, D. A. A. and VAN KUIJK, H. J. L.
A new simple technique for the direct determination of the equilibrium relative humidity of foods. Food Res. 20:415-423, 1955.

A LiCl-cell, developed for the measurement of the dewpoint of air, has been adopted for the estimation of the equilibrium relative humidity of foods, the property which determines, within certain limits, the possibility of microbial spoilage.

The products under investigation were contained in either a gauze basket (in the case of coarse, solid foods only) or in a set of parallel shallow dishes, both coaxial with the LiCl-cell. Cell and containers were immersed in a closed metal vat, equipped with a thermostat-controlled water circulation device. In order to increase the rate of establishment of temperature equilibrium, the LiCl-cell was moreover equipped with a bifilar coil, in series with the water circulation through the wall of the vat.

Values for equilibrium relative humidity obtained in this way for foods and for sodium chloride solutions correlated satisfactorily with the data derived from measurements according to classical techniques.

Determinations according to the new method require considerably less time: one hour at the most, versus at least one day in other electric hygrometers or several days by the older static methods.

239. MUSCO, D. D. and CRUESS, W. V.
Studies on deterioration of walnut meats. J. Agr. Food Chem. 2(10):520-523, 1954.

Rapid deterioration in flavor often shortens the shelf life of walnuts in shelled form. A study of factors showed that deterioration in flavor and odor was accompanied by increase in peroxide and Kreis values, although correlation was not always close. A satisfactory method of determining the peroxide value without expressing the oil was devised. Blanching at 100°C greatly increased the rate of peroxide formation. Lipase appeared to be present and active. Peroxide and Kreis values increased many times faster in oil stored as such than in the meats. Butylated hydroxy-anisole proved more effective in retarding rancidification than did nordihydro-guaiaretic acid, propyl gallate, and antioxidant salt. Light greatly hastened deterioration. Most of

the deterioration is oxidative, although hydrolytic changes may also be involved. Lightproof packaging is desirable. If air is in contact with the meats, an effective antioxidant should be used for long shelf life. Packing under vacuum in cans or jars is the alternative.

240. MYLNE, ANN M. and SEAMANS, VIRGINIA S.
Stabilized orange juice powder. II. Changes during storage. Food Technol. 8:45-50, 1954.

Results of a storage study on orange powder containing added corn sirup solids prepared by a vacuum drying procedure are reported. Effects of atmosphere, type of oil, method of oil addition, in-package desiccation, and added sulfur dioxide on storage stability at 70°F (21°C), 90°F (32°C), and 100°F (38°C) are reported.

241. NATIONAL AGRICULTURAL LIBRARY
Freeze-drying of foods; a list of selected references. U. S. Department of Agriculture Washington, D. C. Library list no.77, 79p., 1963.

242. NELSON, THEODORE J.
Hygroscopicity of sugar and other factors affecting retention of quality. Food Technol. 3:347-351, 1949.

The protection of staple food products during storage is typified by the care given sugar. Studies which have given the basis of present day care are reviewed with particular regard to changes induced by atmospheric moisture. Granulated sugars exposed to a humidity below 60% contain less than 0.03% moisture and this is favored to avoid a lumpiness referred to as caking, whereas unlimited exposure to humidities over 85% will liquify pure sugar. The use of moisture vapor barriers in the package construction, and of caking inhibitors added to the sugar, are discussed; these measures minimize caking in the instance of fine grain sugars to a point equalling results with unprotected coarse grain sugars. Reasons for differences among the various types of sugars are attributed largely to crystal or grain size differences. The retention of other desirable characteristics of granulated sugars, and special care of Brown type sugars are mentioned; Brown sugar requires a surrounding conducive to retaining its natural moist condition.

243. NEMITZ, G.
Hygroscopic properties of dried foods. Z. Lebens.Untersuch. Forsch. 123:1-5, 1963.

Foods (plant and animal, 45 samples) dried in small jars at 40° and 10^{-2}mm. were kept in hygrostats at 13 different R.H. (1.3-97.2) and 20°, over H_2SO_4 of different concentration and saturated

solutions of different salts. The hygrostats were made from 1-l. preserving jars fitted with rotating fans for air circulation. Weekly weighings were made of the (covered) jars until (within 1-4 weeks) equilibrium was reached. Dried tomatoes were the most, and dried peas the least hygroscopic of the vegetable products. Potato starch was the most hygroscopic of the starches. The sugars displayed a wide range of equilibrium, with liquifaction at R. H. above this range. The hygroscopic properties of dried milk, egg, fish and meat products decreased with increasing fat content. In many cases mould growth set in at R.H. 80%. (From J. Sci. Food Agric. 15(3), i-163, 1964).

244. NEWLIN, H. E., MAC MILLAN, JOHN AND SCOTT, BETTY LOU
The development of accelerated storage tests for determining the stability of selected foods. Midwest Research Institute, Report No. 7, Final, 2 May 1955-1 November 1956, 37p. (Contract DA19-129-QM-353), 1956.

A study was made of dehydrated potato granules, dehydrated eggs, and crackers in storage at temperatures from 100° to 140°F for 1 to 7 months to learn whether the sensory and analytic changes could be used as a basis for predicting long term stability. Weekly interval storage tests up to one month on the foods did not indicate limiting values for any of the figures within this period. All of those chemical determinations which gave progressively changing values were felt to be potentially useful in future accelerated storage tests within the temperature range studied. The degree to which these changes followed those of the taste tests possibly measured the correlation between accelerated deterioration in the foods and their actual shelf life.

245. NORDIN, PHILIP and KIM, YEE SIK
Browning and the Amadori rearrangement. J. Agr. Food Chem. 6(10):765-766, 1958.

The browning of glucose with alanine, glycine, and phenylalanine in solution was compared with the browning of the Amadori rearrangement products of glucose and the corresponding amino acids. The rates of browning and the development of ultraviolet spectra for these systems were recorded. The amount of Amadori rearrangement products formed in a browning system was measured.

246. NORRIS, F. A., HILFMAN, LEE J. and LAND, C. E.
Storage of cottonseed. J. Am. Oil Chemists' Soc. 35(12):684-687, 1958.

The moisture content of stored cottonseed depends on the relative humidity of the air which is in contact with it. This is an important

consideration in using air to cool seed in storage since the seed may be moistened or dried as a by-product of the cooling operation. Increasing the moisture tends to increase the FFA and refining loss and thus counteracts the effects of cooling.

Cottonseed can be dried satisfactorily with dry air at ambient temperature or by hot undried air. In either case the economics are not favorable unless a relatively large amount of seed must be dried every season. Equipment and installation costs are relatively high, making carrying charges on the investment of the same magnitude as the probable loss because of deterioration.

247. NOTTER, G. K., TAYLOR, D. H. and DOWNES, N. J.
Orange juice powder. Factors affecting storage stability.
Food Technol. 13:113-118. 1959.

Vacuum-dried orange juice powder containing no additive other than $NaHSO_3$ was stored at 70°, 77°, and 100°F. Changes in flavor and chemical composition were evaluated at intervals during storage.

248. NOTTER, G. K., TAYLOR, D. H. and BREKKE, J. E.
Pineapple juice powder. Food Technol. 12:363-366, 1958.

Pineapple-juice powder of good quality is produced from commercial concentrate by drying at 150°F at 2 mm.Hg pressure for 2 hours and 45 minutes in a vacuum shelf drier. The product is packaged with an in-package desiccant and stored at progressively higher temperatures up to 90°F as the moisture content of the powder decreases. The addition of SO_2 to the concentrate protected the flavor of powders stored at 90°F. If the product is stored at temperatures of 70° to 77°F, there is no need for addition of SO_2 or other preservatives, since the flavor and color changes after one year are negligible. Under conditions of the experiments reported here, vacuum packaging was not found necessary for retention of flavor.

249. _____, _____, and WALKER, L. H.
Stabilized lemonade powder. Food Technol. 9:503-505, 1955.

A method has been developed for making a lemonade powder containing lemon solids, lemon oil, and sucrose in the proportions ordinarily present in lemonade made from fresh lemons. A 65.7° Brix concentrate can be dehydrated in a short period with a pressure of 2mm. and final product temperature of 160°F without undesirable effect on color or flavor of the reconstituted lemonade. The moisture level in the packaged powder can be reduced by in-package desiccation from 1.7% to below 1% in less than two weeks at 80°F. without affecting quality of the product.

250. O'BRIEN, F. E. M.
The control of humidity by saturated salt solutions. J. Sci. Instr. 25:73-76, 1948.

A table of data gives percentage relative humidities over saturated solutions of eighty-eight different salts or salt mixtures. Remarks on the suitability of these solutions for humidity control are included.

251. OLCOTT, H. S.
Antioxidants for fats and oils. 133rd meeting of the American Chemical Society, San Francisco, California (April, 1958.)

252. _____
Deteriorative reactions in stored freeze-dried meat and fish. In Freeze-drying of foods; proceedings of a conference. F. R. Fisher, ed. p.74-76. Washington, National Research Council, 1961.

Storage of freeze-dried meat or fish in oxygen or air is deleterious. Oxidative changes usually occur more rapidly at low moisture content (1-2%) than when higher amounts of water are present. When oxygen is absent, the most important single deteriorative reaction is the carbonyl-amine or Maillard reaction. Enzymes survive in freeze-dried fresh meat and fish products. Enzymatic changes are believed to be comparatively unimportant in low moisture products (less than 3% water). but this facet has not yet been thoroughly investigated.

253. OLSON, R. L. and HARRINGTON, W. O.
Dehydrated mashed potatoes - a review. U. S. Department of Agriculture. AIC 297, 23p. 1951.

This review is concerned with the general characteristics and methods of production of dehydrated mashed potatoes and their advantages over other forms of dehydrated potato (dice, julienne strips, and riced). Patents and other available literature, up to September, 1950, have been searched for information on techniques, analytical procedures, variations in processing factors, and other factors that might be useful in controlling product quality. Storage stability of the product is briefly discussed.

254. OTHMER, DONALD F. and SAWYER, FREDERICK
Correlating adsorption data. Temperature, pressure, concentration, heat. Ind. Eng. Chem. 35(12):1269-1276, 1943.

Equilibrium vapor pressures of gas or vapor adsorbed on activated carbon or other substances are correlated with the temperatures of adsorption and the concentrations of gas or vapor by the graphical

method previously described. The equilibrium vapor pressures of an adsorbate out of a solid adsorbent are plotted against the normal vapor pressures of the same or a different material at corresponding temperatures to give straight lines (isosteres) on a logarithmic plot. The usual advantages of a straight-line relation are obtained; and their slopes are equal to the ratios of the molal heats of adsorption to the molal latent heat of the reference substance. The heats of adsorption may be calculated from this relation; the calculations check calorimetric data closely. These methods of plotting and using data are of help in the design of adsorption systems when only a small amount of data are available.

255. OTHMER, DONALD F. and WHITE, ROBERT E.
Correlating gas solubilities and partial pressure data.
Ind. Eng. Chem. 34(8):952-959, 1942.

A new method of representing gas solubility data has been developed and applied to a number of gas-liquid systems. The representation is graphical and similar to the method applied to vapor pressure of liquids, and described in a previous article. The plot is based upon the equation:

$$\log p = (Q/Q') \log p' + C$$

By considering liquid water and water vapor as the reference system, the equation becomes:

$$\log p = (Q/L) \log P + C$$

A plot of this equation is made on logarithmic scales with vapor pressure of water as the abscissa, the gas partial pressure as the ordinate, and the concentration of the solution as the parameter.

Data for systems obeying Henry's law closely and for systems that deviate widely from it have been plotted in this manner with equal success. In every case the data give lines which may be considered straight within experimental accuracy or lines made up of straight sections of different slopes. An abrupt change in the slope of a line indicates a change in the chemical form in which the gas exists in solution. The straight lines or straight-line sections support the applicability of the plot and also indicate the constancy of the ratio Q/L over ranges involving no chemical change in the gas. From the basic equation the variation of the Henry law constant with temperature may be developed and represented graphically in the same manner.

Heats of solution of gases in liquids may be evaluated readily from the slopes of the lines. This is particularly useful because of the few experimental data available for this important thermal quantity.

256. OTHMER, DONALD F.
Correlating vapor pressure and latent heat data. A new plot. Ind. Eng. Chem. 32:841-856, 1940.

Vapor pressures of liquids, of solids, of solutions having a nonvolatile constituent, of solutions having two or more volatile constituents, of hydrates losing water by efflorescence, and of other materials undergoing decomposition give straight lines when plotted on logarithmic paper against values of the vapor pressures at corresponding temperatures of a reference substance. The slope of the line is equal to the ratio of the latent or other total heat quantity involved in the evolution of the vapor to the latent heat of the reference substance. This indicates the validity of the equation,

$$\log P = L/L' \log P' + C$$

where P and P' are pressures, L and L' molal latent heats, respectively, of the two compounds always taken at the same temperatures, and C is a constant. Plots are made to illustrate the utility of this relation with various materials in checking and correlating vapor pressure data, and it gives lines more nearly straight than are obtained by any other method of plotting which has been suggested.

Latent heats have been evaluated and checked; and heats of fusion, of hydration, of dissociation, of dilution or solution, of chemical reaction, etc., are shown to be related to the method and may be calculated. Freezing points of salt solutions, enthalpy charts, steam distillation relations, composition of vapors from boiling binary solutions, constant-boiling mixtures, and other phenomena relating to the disengaging of vapors from a condensed phase may also be studied and evaluated by this method.

A comprehensive relation is developed which includes all of the other general methods used for graphic vapor pressure representation. Some other useful forms of equations for similar calculations are suggested.

257. _____
Correlating vapor pressure and latent heat data. Use of critical constants. Ind. Eng. Chem. 34(9):1072-1078, 1942.

A simple relation giving highly accurate results has been shown to relate pressures and "reduced latent heats" (i.e., latent heat/critical temperature) of any given material to those of a reference substance, always taken at the same reduced temperature:

$$\log P_R / \log P'_R = L_R / L'_R$$

This equation may be used directly (since there is no constant to evaluate from a plot); and accurate values throughout the entire

range of the vapor pressures and latent heats may be calculated (or read from a readily prepared nomogram) for various compounds, by using single point of reduced temperature and vapor pressure, and values of a reference compound. The equation also gives exact plots and entirely eliminates the slight curvatures in the critical regions of the lines of the logarithmic plot, previously described, for expressing the vapor pressure function. The necessary computations for the interconversion of reduced and usual values of temperatures and pressures may be made graphically by nomograms which are presented. They also allow ready plotting and use when any one standard substance (such as water) is always used as a reference substance.

258. PACKAGING INSTITUTE
Procedure for determination of humidity-moisture equilibria of food products. Test procedure P1 Food. p.1-52, New York, 1952.

259. PAINE, F. A.
Measurement of the moisture penetration of packages. PATRA Packaging Tech. Paper Nr. 3.

260. PALMER, K. J., MERRILL, R. C. and BALLANTYNE, M.
Equilibrium moisture and x-ray diffraction investigations of pectinic and pectic acids. J. Am. Chem. Soc. 70:570-577, 1948.

The equilibrium moisture content at ten relative humidities between zero and 95% are given for seven pectinic and two pectic acids. The moisture content was found to be essentially independent of the methoxyl content.

The free energy change (average about 1600 cal/mole) is considerably higher than found for most proteins.

The BET constants have been calculated. The value of a_1 is nearly the same for all samples and correspond to approximately one water molecule per galacturonic acid unit.

The variation of the equatorially accentuated X-ray reflection with water content has been determined. These results show that the inter-chain distance within the crystalline regions increases with an increase in water content for all samples, except that having the highest methyl ester content (10.9%). In this latter sample the interchain separation appears to be independent of the water content.

261. PALMER, K. J., SHAW, T. M. and BALLANTYNE, M.
X-ray and moisture equilibrium investigation of sodium pectate. J. Polymer Sci. 2(3):318-328, 1947.

The variation of the X-ray reflection related to the interchain separation in sodium pectate has been determined as a function of moisture content. The crystalline regions in sodium pectate have been found to sorb about 24% water (dry basis) at a relative humidity of 95% at 25°C. The sample as a whole under these conditions has a water content of 64%. At high water contents, therefore, a large difference in water content must exist between the crystalline and amorphous regions of sodium pectate. A marked change in degree of crystallinity occurs, as determined by the number and sharpness of the X-ray reflections, at an average water content of about 6% on desorption and on sorption at an average water content of about 14%.

262. PALMER, K. J., DYE, WALTER B. and BLACK, DALE
X-ray diffractometer and microscopic investigation of crystallization of amorphous sucrose. J. Agr. Food Chem. 4:77-81, 1956.

An x-ray diffractometer method has been developed for determining the crystalline-to-amorphous ratio in a spray-dried sample of sucrose. The results obtained by application of this method to samples stored at 30.0 and 32.5% R.H. are discussed. The effect on the rate of crystallizatio of adding 5% finely ground crystalline sucrose to a sample of amorphous sucrose before storage at 30% R.H. has been measured. Observations made on these same samples with a polarizing microscope are used in conjunction with other evidence to postulate a mechanism for the crystallization process in spray-dried amorphous sucrose under the conditions of this experiment.

263. PAP, LEWIS
Hygroscopicity of wheat. Cereal Chem. 8:200-206, 1931.

The hygroscopicity of 286 wheat samples of Hungarian and foreign origin was determined to show the deviations in the moisture content when the samples were stored under the same conditions. Ground wheat samples weighing 2g. which were spread on a surface of 25cm^2 showed a maximal deviation of 1.23% when stored for four weeks in the same closed chamber. When the hysteresis was eliminated by preparing samples of a moisture content of 12% and 13% the greatest difference was 0.86%, the deviation from the average being from -.41% to +0.45%. In 90 percent of the samples the maximum deviation was 0.68+; while 50 percent of them deviated only 0.29%.

For the moisture basis of 12.50% the corresponding value of the relative humidity was 65.3% at 20°C.

The differences in the hygroscopicity of wheat are caused by climate and soil conditions. The influence of the variety is of subordinate importance. No changes are observable in the hygroscopicity whether the wheat is losing or absorbing water.

264. PARTRIDGE, S. M., LEAR, W.E. and WESTALL, R. G.
Dried meat. VI. The effect of water content on the compression characteristics of dried meat. J. Soc. Chem. Ind. T63:16-18, 1944.

The water content of dried meat has an important bearing on its behavior when compressed. If too dry, the dried meat is brittle and the particles become broken down, while if the dried meat is too moist the fibres are so elastic that a considerable expansion takes place after the block has left the press and may culminate in the complete disruption of the block.

A sieve test, suitable for use with dried meat, is described. Using this test, the degree of breakdown on compression has been followed. Compression and relaxation data are given for dried meat of various water contents.

265. PAULING, LINUS
The adsorption of water by proteins. J. Am. Chem. Soc. 67:555-557, 1945.

The data published by Bull and other investigators on the adsorption of water by proteins can be in a considerable degree interpreted on the assumption that the initial process is the attachment of one water molecule to each polar amino-acid side chain. The data also indicate that peptide carbonyl and imido groups usually do not bind water, because of their mutual interaction by hydrogen bond formation, but that water is bound by carbonyl groups which are not coupled by hydrogen bonds with imido groups. In salmin, in which most of the amino-acid residues are polar, these polar residues cooperate to attach one water molecule jointly to two polar groups in the initial process of hydration.

266. PENNY, I. F., VOYLE, C. A. and LAWRIE, R. A.
A comparison of freeze-dried beef muscles of high or low ultimate pH. J. Sci. Food Agr. 14:535-543, 1963.

Some of the deleterious effects of freeze-drying on the texture of beef have been obviated by using muscles with a high ultimate pH. Pre-slaughter injection of adrenaline raised the ultimate pH

to 6.7. After freeze-drying the treated beef was more tender, more juicy and less woody than controls at pH 5.6. A resultant increase in water-holding capacity and rehydratability was demonstrated by myofibrillar swelling and increased fibre diameter. Dehydrated beef with a high ultimate pH showed less deterioration during a storage at 37° in the attributes texture, flavor and color.

267. POERSCH, W.
Sorptionsisothermen, ihre Ermittlung und Auswertung, (Sorption isotherms, their determination and evaluation) Stärke 15(11): 405-412, 1963.

After a short introduction to the sorption mechanism and the importance of sorptions isotherms, a report is made on the determination and evaluation of sorptions and desorptions isotherms, made in a comparatively simple apparatus, the examples being corn starch and corn hull feed. Short reference is made to the interpolation of isotherms for other temperatures desired, two isotherms recorded at two different temperatures. Further, it is shown how over the isoesters found in the isotherms, by a simple thermodynamic relation, the sorption heat becoming free in the sorption process and needed in the desorption process can be determined. In conclusion, there is a short reference to the BET theory in comparison with the graphs recorded.

268. POOL, M. F. and KLOSE, A. A.
Estimation of monocarbonyl compounds in rancid foods. J. Am. Oil Chemists' Soc. 28:215-218, 1951.

A convenient method for the determination of monocarbonyl compounds in rancid foods is described. The quantitative procedure is based on the formation of the 2, 4-dinitrophenylhydrazones of monocarbonyl compounds in benzene solution, the removal of excess hydrazine reagent and the hydrazones of dicarbonyl compounds with alumina, and the colorimetric determination of the remaining hydrazones of monocarbonyl compounds in alkaline solution. Applicability to aldehydes varying in molecular size and degree of unsaturation has been demonstrated. The method may be used on the crude benzene extracts of rancid foods. Illustrative data are presented.

269. POWERS, H. E. C.
Refined sugar moisture. Intern. Sugar J. 56:314-315, 1954.

A pure sucrose solution, under normal conditions of temperature and pressure, will be in equilibrium with atmosphere of about 86% relative humidity. A very impure syrup, like a molasses, will probably have an "E.R.H." (equilibrium relative humidity) of well under 60%. The refiner should dry sugar to where it will be in

equilibrium with relative humidity of its storage atmosphere. If it is not dried to this point, it will continue to dry in storage and tend to cake. If dried beyond this point, it will pick up moisture until it reaches equilibrium. Thus no guarantee of water content can be valid unless the sugar is packed in moisture vapor-proof packing or the non-sugars in the surface layer are reduced to very low levels, both of which would add so much to the cost of the sugar as to make them uneconomic.

270. PRATER, A. N., JOHNSON, C. M., POOL, M. F. and MacKINNEY, G. Determination of sulfur dioxide in dehydrated foods. Ind. Eng. Chem., Anal. Ed. 16(3):153-157, 1944.

Details are presented of a rapid direct titration method for determining sulfur dioxide in dehydrated foods. The reliability of the method has been established by recovery of added sulfur dioxide and by comparison with distillation and polarographic methods.

271. PRUTHI, J. S., SINGH, L. J. and LAL, GIRDHARI
The equilibrium relative humidity of garlic powder. J. Sci. Food Agr. 10(7):359-361, 1959.

Based on sorption isotherms or equilibrium relative humidity curves, the packaging characteristics of garlic powder have been determined. It is shown that (1) garlic powder is a highly hygroscopic product, picking up moisture even at 20% R.H.: (2) for a typical garlic powder (moisture 6%), the equilibrium relative humidity at 25° is about 13%; (3) the critical point for garlic powder as regards caking was found to be at 10.6% moisture level, and the danger point at 9.5%.

272. PUGACHEV, P. I. and SHABANOVA, V. A.
Izmenenie belkov pri khranenii belogo kurinogo myasa obezvozhennogo sublimatsionnoi sushkoi. (Changes in protein during storage of hen white meat dried by sublimation) Vysshykh Uchebhykh Zavedekii. Pishchevaya Tekhnologiya 6:85-87, 1961.

The H_2O and salt-sol. protein-N fractions of hen white meat decreased slightly during storage (1 year and 17 months) of meat dried by sublimation, and the alkali-solution fraction increased.

273. PURR, ARNULF and HEISS, RUDOLF
Influence of relative atmospheric moisture on chemical processes during the storage of whole milk chocolates and of mill and spray whole milk powders used in their production. I. Introductory tests on the permissible or optimum water contents.

Fette, Seifen Anstrichmittel 65:1018-1022, 1963. Same article in Rev. Int. Choc. (RIC) 19(5):190, 192, 194, 196, 1964.

It was supposed that the changes, which take place in milk-chocolate during storage, depend on changes of the applied milk. For explanation the sorption-isothermes of whole-milk-powders, produced in two different ways, were ascertained, the optimal and critical values were organoleptically fixed and these were compared with the sorption-isothermes of chocolates, produced with these whole-milk-powders. The conformity between the organoleptically determined values and the monomolecular covering according to BET, however, unfavorable. With the aid of the Warburg-method the optimal values could be explained form the increasing browning reactions with growing moisture with the aid of increasing autoxidation of the milk fat by decreasing moisture.

274. PURR, ARNULF
Influence of relative atmospheric moisture on chemical processes during the storage of whole milk chocolates and of mill and spray whole milk powders used in their production. II. The reason for quality deterioration and its analytical character. Fette Seifen Anstrichmittel 65:1023-1030, 1963.

The experimental results give the right information on the nature of the storage-changes of full-milk-chocolates and full-milk-powders, described in the I. communication and which are characteristic for the beginning of the Maillard-conversions. In this connection the HMF-determination, the lysin-and lactose-analysis and the gas-chromatographic analysis of carboxyl compounds show themselves as valuable analytical procedures for the judgement of the quality of above mentioned products.

275. RAO. KITTUR SUBBA
Disappearance of the hysteresis loop. The role of elasticity of organogels in hysteresis in sorption. Sorption of water on some cereals. J. Phys. Chem. 45:531-539, 1941.

Sorption of H_2O on activated rice and dal grains exhibits a unique disappearance of a hysteresis loop initially present. The disappearance is explained on the basis of the elasticity of organic gels which swell on imbibition of H_2O. On rice, CCl_4 exhibits a reproducible and permanent hysteresis; the adsorption of CCl_4 is only one-twentieth as great as that of H_2O.

276. REGIER, L. W. and TAPPEL, A. L.
Freeze-dried meat. III. Non-oxidative deterioration of freeze-dried beef. Food Res. 21:630-638, 1956.

The study purported to point out the main physical and chemical changes that take place during the deterioration of freeze-dried beef

in storage. Concluded that the only important non-oxidative deterioration of the meat was active carbonyl-amine browning. There was no loss in protein nutritive value in freeze-dried meat that was made organoleptically unacceptable due to deterioration. (From Nat. Agric. Lib., Library list no. 77, 1963)

277. REGIER, L. W. and TAPPEL, A. L.
Freeze-dried meat. IV. Factors affecting the rate of deterioration. Food Res. 21:640-649, 1956.

The apparent activation energy for the deterioration of freeze-dried beef during storage is 25 kcal/mole. This lends further support to the conclusion that browning is the major deteriorative reaction and eliminates the possibility of a significant amount of thermal denaturation.

The carbonyl compounds are the limiting reactants in the browning of freeze-dried beef. Lowering the pH causes a decrease in the rate of deterioration. The volatile compounds produced in the deterioration of freeze-dried beef apparently do not enter into further reactions, but are possibly end- or side-products of the deterioration.

Essentially complete removal of water does not eliminate the storage deterioration. Moisture level is very important in the storage stability in that the rate of deterioration is increased with increasing moisture level.

Possible methods for increasing storage life of freeze-dried beef are discussed.

278. _____, EMERSON, M. R., TAPPEL, A. L., CONROY, A. and STEWART, G. F.
The preparation and storage stability of freeze-dried beef. Food Technol. 8. Technical program and abstracts of the 14th Annual Meeting of the Institute of Food Technologists. Paper No. 162. (p.42) 1954.

One-inch-thick pieces of the muscle biceps femoris were freeze-dried by two commercial techniques. Conventional plate freeze-drying was more successful than infra-red radiation. The freeze-dried beef has a pink color and re-hydrates to about 85% of its original moisture. When cooked, the freeze-dried beef was similar to the fresh controls except for a slightly drier texture and browner color.

During storage at 100°F the freeze-dried beef undergoes pronounced deterioration. Production of fluorescence, reducing compounds, brown

coloration, and a loss of sugars and rehydratability indicate that "amine-active aldehyde" browning is a predominate deteriorative mechanism. The red color of oxy-hemoglobin and oxy-myoglobin is lost during storage by an oxidation of the pigments to methemoglobin and metmyglobin. Storage in atmospheres containing oxygen induces more rapid deterioration involving unsaturated liquid oxidation and other unidentified oxidative reactions.

Storage stability has been increased by (1) packing in pure nitrogen atmospheres to prevent oxidative deterioration, (2) in-package desiccation to lower the water content and thereby decrease the browning reaction, (3) conversion of the heme pigments to their stable carbon monoxide derivatives.

279. REY, LOUIS R. and BASTIEN, MARIE-CLAUDE
Biophysical aspects of freeze-drying. Importance of the preliminary freezing and sublimation periods. In Freeze-drying of foods; proceedings of a conference. p.25-42. Washington, Nat. Res. Council. 1962.

Points out the three main types of products that can be freeze-dried and the minimum requirements for successful operation in each group. Various experiments are presented showing aspects of problems involved. Emphasizes the necessity of processing each given product in its own particular way. (From Nat. Agric. Lib., Library list no. 77, 1963)

280. REYNOLDS, T. M.
Chemistry of non-enzymic browning. I. The reaction between aldoses and amines. Advances in Food Research 12:1-52, 1963.

This paper on nonenzymic browning in foods is confined to a discussion of the reactions between aldoses and simple amines.

281. RICHARDS, E. L. and CHANDRASEKHARA, M. R.
Chemical changes in dried skim-milk during storage. J. Dairy Res. 27:59-66, 1960.

Dried skim-milk stored at 55°C in air at 70%relative humidity has been found to contain lactulose, galactose, tagatose, glyceraldehyde and maltol; and formic, acetic and glycollic acids. These compounds are not present, or are present only in trace quantities, in fresh dried skim-milk. It is suggested that while the protein-sugar reaction is responsible for most of the browning of the powder, many of the compounds found are formed by degradation of lactose catalysed by the free basic amino groups of the casein. The compounds so formed probably then react with amino groups in a Maillard reaction and thus contribute to the browning of the milk powder.

282. RICHARDS, E. L.
Non-enzymic browning: the reaction between d-glucose and glycine in the 'dry' state. Biochem. J. 64:639-644, 1956.

The reaction between D-glucose and glycine in the "dry" state at 37°C, pH 6.7 and 70% relative humidity has been studied chromatographically and spectroscopically. An intermediate appeared which gave the color reactions of both a sugar and an amino acid. On the evidence obtained the intermediate has been formulated as the enolic form of N-(carboxymethyl)-amino-1-deoxyfructose, with the tautomeric equilibrium completely in favor of the enol. The compound has been shown to be a true intermediate in the "browning" reaction.

283. _____
A quantitative study of changes in dried skim-milk and lactose-casein in the 'dry' state during storage. J. Dairy Res.30(2): 223-234, 1963.

Changes in dried skim-milk and in lactose-casein in the 'dry' state during storage at 45°C and 75% r.h. have been studied by the determination of free amino-N, E-amino groups of lysine, galactose, lactulose, tagatose and 1-amino-1-deoxy-2-ketoses, and by the measurement of changes in color, solubility and ferricyanide reducing power.

In both systems there is initially a close relationship between the formation of 1-amino-1-deoxy-2-ketoses and the decrease in free amino-N. This conforms with an Amadori rearrangement of an initially formed lactose-protein complex. Change in color is rapid only after there has been a rapid formation of 1-amino-1-deoxy-2-ketoses and a corresponding decrease in free amino-N. This conforms with browning being due to a breakdown of the Amadori rearranged complex.

It is postulated that galactose and tagatose may be formed by both the base-catalysed degradation of lactose and also by breakdown of the Amadori rearranged lactose-protein complex. Lactulose is postulated to be formed only by base-catalysed degradation of lactose.

284. RICHARDSON, G. M. and MALTHUS, R. S.
Salts for static control of humidity at relatively low levels. J. Appl. Chem. 5:557-567, 1955.

An isopiestic technique has been used for observing the static control of humidity by saturated salt solutions and by paired salt hydrates. Many new values within the range 7% to 60% relative humidity at 25°C have been obtained, using saturated solutions of highly soluble salts. Difficulties encountered in using paired salt hydrates to control humidity at low levels have been described.

285. RINFRET, A. P.
Biochemical aspects of damage in freezing and freeze-drying of biological materials. In Freeze-drying of foods; proceedings of a conference. p.43-49. Washington, Nat. Res. Council, 1962.

With regard to foodstuffs, the main reactions leading to degradation seem to be the oxidation of pigment, the oxidation of proteins and lipid, and the so-called browning reaction. This last reaction is closely connected with storage temperature and residual water content of the dried food. (From Nat. Agric. Lib., Library list no. 77, 1963).

286. ROBY, MABRY T. and SIMON, MORRIS
Improvement of potato granule quality by fluidized bed finish drying. Food Technol. 13(6):327-331, 1959.

Fluidized bed finish drying has been shown to be a practical means of obtaining moisture levels of as low as 5% in potato granules. (Levels even lower than 5% can be obtained but only with some sacrifice of product quality.) The attainment of moisture levels lower than required by the military specification for potato granules (7%) by this process does not impair product quality initially or after extensive storage, but on the contrary increases quality. Consumer preference and other analytical data, obtained from a 2-year storage study conducted at the Quartermaster Food and Container Institute for the Armed Forces, indicates the superiority of fluidized bed finish dried potato granules over those pneumatically dried. It is shown that the increased acceptance and storage stability of fluidized bed finish dried potatoes was due to a lesser degree of incipent heat damage during dehydration.

287. ROCKLAND, LOUIS B.
A new treatment of hygroscopic equilibria: application to walnuts (Juglans regia) and other foods. Food Res. 22:604-628, 1957.

Procedures have been developed for the rapid estimation of moisture in both shelled and in-shell walnuts. Moisture sorption isotherms have been determined for various samples of both in-shell and shelled walnuts. It has been suggested that moisture sorption isotherms are composed of multiple, but most generally three "localized isotherms", each of which may represent a special type of water binding. The total moisture sorption isotherm is obtained by coupling the portions of the individual "localized isotherms" which corresponds to the portion of the relative humidity scale for which each of the "localized isotherms" is valid. "Localized isotherm" constants have been presented for 45 food products. The differential coefficient of moisture with respect to relative humidity ($\Delta M/\Delta$ rh), which can be

calculated from moisture sorption isotherms, may be related to stability characteristics of shelled walnuts and beans during storage.

288. RODRIGUEZ-ARIAS, JORGE H.
Desorption isotherms and drying rates of shelled corn in the temperature range of 40° to 140°F Ph.D. Thesis, Michigan State Univ.205p,1956.

289. ROSS, A. FRANK
Deterioration of processed potatoes. Advances in Food Research 1:257-290, 1948.

Browning which is due to a reaction between reducing sugars and amino acids frequently occurs in dehydrated potatoes, either during processing or during storage. The rate of discoloration is affected by moisture content and temperature, as well as the reducing sugars content. Sulfiting inhibits the browning reaction. It also inhibits the gray discoloration encountered in dehydrated potatoes during low temperature storage. Packaging in inert atmospheres has little effect on browning, but packaging with calcium oxide as an in-can desiccant will bring about a satisfactory low-moisture level. Thus, increase in storage life of dehydrated potatoes can be attained by using potatoes of low reducing sugars content, by sulfiting, and attaining a low-moisture content in packaging.

290. ROSS, A. FRANK, HILBORN, T., JENESS, LYLE C. and BARTLETT, EMILY M.
Selecting and storing potatoes to avoid darkening. Food Ind. 18:1011-1013, 1144, 1146, 1148, 1150, 1152, 1946.

Influence on finished product of reducing sugars in raw potatoes, how reducing sugars vary with storage conditions and variety, and what to do to reestablish equilibrium are all discussed in this article.

291. SAIR, L. and FETZER, W. R.
The determination of moisture in the wet milling industry, Cereal Chem. 19:633-720, 1942.

This article has 6 parts and an appendix. It compares methods of determining moisture in corn and corn products. The moisture contents of samples of corn and corn products were determined by several different methods. Other tests indicate that the various methods in use by the corn products industry still underestimate the moisture by 0.8% to 1.8%. The results of these investigations have led to the recommendation of two official reference moisture methods within the wet milling industry. Both determine moisture directly. The toluene distillation method is to be used with stable products, which include corn, hulls, corn gluten, gluten meal, and corn oil meal. The benzene distillation is used for the unstable products, which include gluten feed, steep water, and sweetened feeds.

292. SALWIN, HAROLD
Defining minimum moisture contents for dehydrated foods. Food Technol. 13(10):594-595, 1959.

Moisture transfer among the components of the quick-serve ration of the Armed Forces can lead to browning, crystallization and caking

defects. The moisture sorption properties of a large variety of precooked dehydrated foods were determined in order to predict packaging compatability with respect to moisture transfer. By applying the adsorption theory of Brunauer, Emmett and Teller (B.E.T.) to vapor pressure data of individual foods, it was observed that the moisture content specified for good stability agreed very closely with the amount which represented a statistical monomolecular layer of adsorbed water for most of the foods. This monomolecular layer may act as a protective film for the food.

293. SALWIN, HAROLD
Moisture levels required for stability in dehydrated foods. Food Technol. 17(9):34-35, 38-40, 43. (1114-1115, 1118-1120, 1123 1963) Also in Research & Development Associates, Food and Container Institute Activities Report, 13:191-199 (1961) Latest version was revised and updated.

Moisture-sorption data give useful guidance for processing and packaging dehydrated foods. In most cases, the monomolecular-layer moisture content is a good first target in dehydration when specific stability data are lacking. The compatibility of items which are to be packaged together can be determined with good reliability. Consideration should be given to the broader use of moisture-vapor pressure measurements which can be more meaningful than moisture determinations on dehydrated food. The loss in weight over magnesium perchlorate in a vacuum desiccator at 40°F provides a close approximation of the true moisture content of dehydrated foods that contain volatile constituents.

294. SALWIN, HAROLD AND SLAWSON, VIDA
Moisture transfer in combinations of dehydrated foods. Food Technol. 13(12):715-718, 1959.

Dehydrated foods normally have good shelf life if the moisture content is maintained within narrow limits. Stability is impaired in mixtures of dehydrated foods in which there is a transfer of water from items of higher moisture-vapor pressure to those of lower moisture-vapor pressure.

Isotherms which show the relationships between moisture content and vapor pressure (or relative humidity) of the components of a food mixture provide guidance as to their packaging compatability. A formula is presented for computing from the isotherms the equilibrium relative humidity of such mixtures and the final equilibrium moisture content of each component. Data are presented which show the close agreement between final moisture contents calculated by the formula and values determined experimentally.

295. SALWIN, HAROLD
The role of moisture in deteriorative reactions of dehydrated foods. In Freeze-drying of foods; proceedings of a conference. p.58-74, Washington, Nat. Res. Council, 1962.

Moisture-sorption data give useful guidance for processing and packaging dehydrated foods. In most cases, the monomolecular-layer moisture content is a good first target in dehydration when specific stability data are lacking. The compatibility of items which are to be packaged together can be determined with good reliability. Consideration should be given to the broader use of moisture-vapor pressure measurements which can be more meaningful than moisture determinations on dehydrated foods. (From summary)

Many studies are reviewed with such freeze-dried items as carrots, pork chops, peaches, apple slices, fruit cocktail. Among observations made here, moisture-vapor pressure measurements were found to be more meaningful than moisture determinations of dehydrated foods. In processing and packaging dehydrated foods, moisture-sorption data are important. (From Nat. Agric. Lib., Library list no. 77, 1963).

296. SARAVACOS, G. D. and CHARM, S.E.
Effect of surface-active agents on the dehydration of fruits and vegetables. Food Technol. 16:91-93, 1962.

Treatment of porous fruits (e.g., apples and peaches) with surfactant before dehydration was found to increase the drying rate during the early period of drying (constant-rate period). There was no significant effect of the surfactants on the drying rates of vegetables (potatoes, carrots, onions, garlic) and seedless grapes. In all cases the surfactants had no effect on the falling-rate period of drying. The equilibrium moisture contents and the rehydration ratios of the fruits and vegetables studied were not affected in general by the surfactant pretreatment. The shrinkage properties of potatoes and apples during dehydration were unaffected by the surfactants.

297. SARAVACOS, GEORGE D.
Freeze-drying rates and water sorption of model food gels. Food Technol. 19(4):625-629, 1965.

The freeze-drying rates and water sorption of starch, gelatin, pectin, cellulose gum, and egg albumen were studied. The equilibrium moisture-sorption isotherms of freeze-dried gels at 30°C were similar to the isotherms of air-dehydrated materials.

298. SARAVACOS, G. D. and CHARM, S. E.
A study of the mechanism of fruit and vegetable dehydration. Food Technol. 16(1):78-81, 1962.

Four vegetables and four fruits were dehydrated in an air dryer, and drying-rate curves were constructed. Constant-rate periods were found in most materials, and the critical moisture contents were characteristic for each food and for given drying conditions. The drying data followed the equation $\ln\left(\frac{W - W_e}{W_c - W_e}\right) = -mo$ in the region of moisture contents W = 1.0 to 0.1, and the values of the drying constant (m) were determined for a set of conditions.

A study was made of the effect of the air-drying conditions and the size of the material on the drying rate of potatoes. A small increase in drying rate during the constant-rate period was effected by increasing air velocity or decreasing air humidity, but these variables did not affect the falling-rate period. The drying time was found to be proportional to the square of the thickness of the potato slabs. Blanching potatoes before dehydration had no effect on drying rate. These results suggested that moisture transfer during the falling-rate period in potatoes is by molecular diffusion. The diffusivity of moisture in the potato was calculated, and it was found to increase with temperature, following the Arrhenius equation.

299. SCHORMUELLER, J., ANDRAESS, W., LANGE, H. J. and MUELLER, K. H.
Influence of chemical transformation during drying of food mixtures with respect to storability. I. Introduction, analytical methods, and description of the problem. Z. Lebensm. Untersuch. Forsch. 117:379-389, 1962.

Analytical methods used in studies of various changes in dried products (amino acid-sugar mixtures, dried skim milk, dried soups) are presented for moisture, total acids, L(+)-glutamic acid, L(+)-lysine, L(+)-arginine, total and acid solution amine acids, reducing sugars, sugars after inversion, glucose, reductone, 5-hydroxy-methylfurfural (detection of beginning of the Maillard reaction), visual browning, and lycopene color. (CA 57 12963)

300. _____ and _____
Influence of chemical changes during drying of foods for storage stability. II. Study of model mixtures. Z. Lebensm.Untersuch. Forsch. 118:12-22. Einfluss chemischer Umsetzungen bei trockenen Lebensmittelgemischen in Hinsicht auf die Lagerfestigkeit. II. Untersuchungen an Modellgemischen, 1962.

Lysine (I), arginine (II), and glutamic acid (III), with glucose lactose, and spray dried milk were studied for Maillard reaction activity

as determined by changes analytically determined constituents after storage at 60°, 100°, and 105°, respectively, over periods up to 76 days. On a III-sugar system in dry media, III is unaffected at 100° but is destroyed in presence of moisture. It is inactivated 50-times faster than I at the low temperature. Reaction of III is 700-times faster at 105° than at 60°. I in dried milk treated 1 hour at 100° and 100% relative humidity becomes unreleasable with enzymes; with dry heating 1 hour at 105° the injury to the I is 72%. There is less loss of II in comparison with I with respect to the Maillard reaction; loss of II in dry heat is 30% and is greater with moist heat. Analytical data for residual sugars with enzymic methods after the Maillard reaction showed great variations. In all cases, the Maillard reaction begins rapidly and slows down quite rapidly. An important criterion for injury to amino acids is the hydrolyzability of the Maillard product, which is split to a greater extent by 6.6N HCl than by enzymes; considerable data on the enzyme and acid hydrolyzability of the reaction mixtures are given. Data are also presented on the spectrographic changes in dried milks heated 22-102 hours at 100 and 105°.

301. SCHORMUELLER, J. and ANDRAESS, W.
Influence of chemical changes on drying food mixtures with respect to storability. III. Studies on food mixtures and on one dried soup. Z. Lebensm. Untersuch. Forsch. 118:112-116, 1962. III. Untersuchungen an Lebensmittelgemischen und an einer Trockensuppe.

Mixture of dried skim milk: onion powder: glutamate (80:15:5) and of dried skim milk: tomato powder: glutamate (70:25:5) were stored 408 days at 70% relative humidity at -20 and 30°. At 30°, 69-72% of the lysine and 14-24% of the arginine were lost, beside considerable sugar. With a dried veal soup preparation stored similarly and at 20° there was 3 times more loss of lysine at 30° than at 20° and the products became inedible. The loss of lysine is nutritionally most critical.

302. _____ and LANGE, H. J.
Influence of chemical changes on drying food mixtures with respect to storability. IV. Further studies on food mixtures. Z. Lebensm. Untersuch. Forsch. 118:116-127, 1962.

Data and information are developed pertinent to storage of dried foods. The respective odors and colors developed on heating 12 pure amino acids with glucose to 100° are tabulated. Heating was continued, and the temperature at which browning develops, and aromas at 180° are recorded. Changes in moisture, sugars, reductone, lysine, glutamic acid, and total amino acids over a 400-day storage test at 30 and 20° are graphically presented for tomato powder, carrot flakes, meat extracts and a mixture of meat extracts, onion powder, and momo-Na glutamate. The data are supplemented with tabulated observations on

odor, taste, and color. Stored at 20 and 30°, 3 dried tomato soups were so affected in odor, taste, and color as to be unsalable. Storage in the absence of O was recommended.

303. SCHORMUELLER, J. and LANGE, H. J.
Influence of chemical changes during drying of food mixtures with regard to storability. V. Determining color changes and their first stages in tomato products. Z. Lebensm. Untersuch. Forsch. 118:214-223, 1962.

Storability at 0° - 30°, 70% relative humidity, with drying agents, and under N of dried tomato powder, tomato fruit pulp, and dried tomato soup was studied. Degree of browning, lycopene content (index for beginning of changes) and hydroxy-methylfurfural (I) content were determined at periods up to 370 days storage. I. development was most suitable for determination of the induction periods and analytical characterizing the course of the reaction.

304. _____ and MUELLER, K. H.
Influence of chemical changes during drying of foods for storage stability. VI. Food mixtures having dried skim milk as the principal component. Z. Lebensm. Untersuch. Forsch. 118:485-491, 1963.

Food mixtures, (A) skim milk, green beans, glutamate, and (B) skim milk, meat extract -salt mixture, glutamate, were studied throughout 560-day storage period at 3, 20, and 30° for changes pertinent to the Maillard reaction. The content of lysine and arginine decreased considerably; glutamic acid decreased slightly; and total amino N paralleled the general decrease of the amino acids. Among sugars, glucose showed greatest loss. Total acids and moisture increased during storage. B was less stable than A.

305. SCOTT, W. J.
Water relations of food spoilage microorganisms. Advances in Food Research 7:83-127, 1957.

Water requirements, and factors affecting these requirements, for the growth of molds, yeasts and bacteria are reviewed. Some applications in the preservation of fresh, dried, concentrated, frozen and canned foods are discussed.

306. SEEHOF, JERROLD, M., KEILIN, BERTRAM and BENSON, SIDNEY W.
The surface areas of proteins. V. The mechanism of water sorption. J. Am. Chem. Soc. 75:2427-2430, 1953.

The sorption of water by solid proteins is characterized by the evolution of heat, a peculiar hysteresis, swelling of the solid and

an increase in the BET surface area of the solid. Heat evolution is of the order of magnitude of the heat of vaporization of water and in conjunction with the poor thermal conductivity of the protein acts to slow the sorption considerably. The hysteresis is unusual in that it is almost constant over the entire range of partial pressures from about p/f =0.05 to 0.90 and independent of temperature. Although the hysteresis loop is quite reproducible (i.e., in both branches)the sorption-desorption curves do not correspond to states of thermodynamic equilibrium and thermodynamic data calculated from them are apt to be quite anomalous. It is observed that the surface areas of proteins as measured by the BET method show an increase after water sorption which is reproducible and can be interpreted in terms of particle dimensions to give an apparent molar density for water which is anomalously high and indicates rather unusual packing efficiency in the solid. It is proposed that the hysteresis is associated with binding on the free basic groups of the protein. The existing data on sorption do indeed show an excellent correlation between number of free basic groups and the maximum amount of hysteresis and a hypothesis is suggested for such a correlation.

307. SHARP, J. G. and ROLFE, E. J.
Deterioration of dehydrated meat during storage. In Fundamental Aspects of the Dehydration of Foodstuffs. p.197-210, Society of Chemical Industry, London, 1958.

Freeze-dried beef, lamb, and pork were used in the studies. Both raw and pre-cooked meats were investigated. Details of the experiments are given and conclusions listed. Although all dehydrated meats (regardless of the method of preparation) deteriorate in storage, the storage life can be lengthened by drying to very low moisture contents. More rapid systems of freeze-drying have been developed to achieve these low levels more economically. (From Nat. Agric. Lib., Library list no. 77, 1963).

308. SHARP, J. G.
Deterioration of dehydrated meat during storage. I. Non-enzymic deterioration in absence of oxygen at tropical temperatures. J. Sci. Food Agr. 8(1):14-20, 1957.

The deterioration in quality of dehydrated precooked pork which takes place during storage even in absence of oxygen would appear to be due to a typical carbonyl-amino browning reaction. The effects of moisture content and temperature on the changes have been studied. The reactive sugar fraction in meat consists mainly of free glucose

and glucose-6-phosphate. Although the sugar fraction produces a brown discoloration by reaction with either the protein fraction or non-protein soluble fraction, the characteristic bitter, burnt flavors of stored dehydrated meat are produced only by reaction with the non-protein fraction.

The reaction can be inhibited entirely by storage in nitrogen containing 500 ppm of sulphur dioxide or by removal of the reducing sugar and glucose-6-phosphate by fermentation with high concentrations of yeast. Partial inhibition is achieved by fermentation of the free sugars only, by lower concentrations of yeast or by oxidation of the free glucose only, by glucose oxidase.

309. SHARP, J. G.
Deterioration of dehydrated meat during storage. II. Effect of pH and temperature on browning changes in dehydrated aqueous extracts. J. Sci. Food Agr. 8(1):21-25, 1957.

The rate of development of brown discoloration in dehydrated aqueous extracts of meat has been shown to increase with pH over the range 3 to 7.

The Q_{10} of the rates of loss of free sugar and development of brown discoloration in such extracts during storage in the range 15° to 50° are the same and lie between 3.2 and 4.3.

310. SHARP, J. G.
Non-enzymic browning deterioration in dehydrated meat. In Recent Advances in Food Science, v.2, p.65-73. J. Hawthorne and J. M. Leitch, ed. London, Butterworths, 1962.

All dehydrated meat suffer deterioration to a greater or lesser degree during subsequent storage. In the absence of oxygen, the main changes are caused by the reducing sugars-amino acids reaction. Deterioration in precooked freeze-dried pork during storage at 37° and 50°C was studied in detail. Results indicate that the development of brown discoloration together with typical strong burnt flavors occurred only in samples containing both reducing sugars and the aqueous soluble substances of the meat. The insoluble protein residue reacted with glucose to give a brown product which, however, was relatively tasteless. At low moisture of 16% equilibrium relative humidity and below, the rate and degree of deterioration of freeze-dried raw and cooked meat are very similar. At higher levels the rate of change is greater in raw meat than cooked meat.

311. SHARP, PAUL F. and DOOB, HUGO JR.
Effect of humidity on moisture content and forms of lactose in dried whey. J. Dairy Sci. 24:679-690, 1941.

Dried wheys contain both the alpha and beta forms of crystallized lactose. Stabilized dried wheys do not absorb excessive amounts of water until the relative humidity exceeds 40 to 50%. The lower the percentage of lactose in the dry matter, the greater the equilibrium moisture content of the dried whey at constant relative humidity.

312. SHAW, T. M., ELSKEN, R. H. and KUNSMAN, C. H.
Moisture determination of foods by hydrogen nuclei magnetic resonance. J. Assoc. Offic. Agr. Chemists 36:1070-1076, 1953.

Results of experiments show that the nuclear magnetic resonance absorption due to hydrogen nuclei can be used to measure the water content of food materials. The principal limitation on the precision of the method appears to be the lack of reproducibility of the packing or non-uniformity of test specimens. It appears possible that this limitation may be substantially reduced by appropriate changes in the experimental conditions. Such means are currently being investigated.

313. SHAW, T. M.
The surface area of crystalline egg albumen. J. Chem. Phys. 12:391-392, 1944.

Recent adsorption measurements were made on crystalline egg albumin. The Brunauer, Emmett, and Teller (BET) method was used for the determination of specific surface areas. As in the case of montmorillonite, the measurements revealed a large difference between the surface areas available to water vapor and that available to nitrogen. In the case of montmorillonite it has been shown that this discrepancy is due to the penetration of water in the polar region between the silicate layers. This region is not penetrated by nitrogen. A similar behavior can account for the surface areas obtained for egg albumin.

314. SHIVASHANKAR, S. and GOVINDARAJAN, V. S.
Equilibrium relative humidity relationships of processed arecanut and whole dried ripe nuts. Food Sci., Mysore 12:317-321, 1963.

Data on equilibrium R.H., equilibrium moisture content and critical and permissible levels of moisture for three types of processed mature green arecanuts and whole dried ripe arecanut were determined. (J. Sci. Fd. Agric. 15 (7)).

315. SIDDAPPA, G. S. and NANJUNDASWAMY, A. M.
Equilibrium relative humidity (ERH) of fruit juice and custard powders. Food Technol. 14:533-537, 1960.

Mango and guava powders have almost similar moisture equilibrium curves, while orange juice and mango custard powders have curves that differ significantly from these and from each other. The graphical interpolation method is quicker than the wt. equilibrium method but the latter gives more precise determination of ERH and information regarding storage behavior in relation to danger and critical points and safe margin. Mango and guava powders and mango custard powder have a wider safety margin (4, 10, and 14% R.H.) than orange juice powder (1% R.H.); all have tendency to develop mould when R.H. of storage atm. exceeds 80%. (J. Sci. Food Agric. 1961, i-145).

316. SIDWELL, C. G., SALWIN, H. and KOCH, R. B.
The molecular oxygen content of dehydrated foods. J. Food Sci. 27(3):255-261, 1962.

Describes a polarographic method for measuring oxygen content. Freeze-dried beef, chicken, and carrots were used in the study. (From Nat. Agric. Lib., Library list no. 77, 1963)

317. SINCLAIR, A. T. and McCALLA, A. G.
The influence of lipoids on the quality and keeping properties of flour. Can. J. Res. 15C:187-203, 1937.

The keeping properties of different flours varied considerably. Aging was accompanied by increased absorption regardless of whether the flour deteriorated in baking quality. Increased acidity developed in all flours, but was not a good measure of deterioration. Storage in sealed containers favored acidity increases, while storage in sacks favored deterioration. A decrease in ether extract accompanied deterioration, while decrease in the less soluble lipids appeared to take place in all samples.

The changes in the physical properties of gluten gave the best indication of deterioration. Gluten from deteriorated flour was harsh, spongy and short, and could not be completely dispersed in sodium salicylate. Unsaturated fatty acids added to flour had the same effects on gluten, but not on baking quality. Ground wheat germ added to deteriorated flour improved the gluten and restored its solubility. The more insoluble germ lipoids were the effective substances. Alcohol extraction of flour caused deterioration, but gluten quality was largely restored by addition of germ. All results indicate the lipoids are adsorbed on the protein of gluten.

It is concluded that the unique physical properties of gluten are to a considerable extent dependent on the relatively insoluble lipoids present. The possibility of gluten denaturation being a breakdown of the protein-lipoid complex is discussed.

318. SING, K. S.
The monolayer capacity in the physical adsorption of gases on solids. Chem. Ind. (London) (Feb 22, 1964), 321-322, 1964.

Point B, which has physical significance as the true monolayer capacity, was defined by Emmett and Brunauer as the point marking the beginning of the middle linear region of the S-shaped isotherm. Agreement between point B and Vm, the Brunauer-Emmett-Teller (BET) monolayer capacity, is not always satisfactory. Comparisons were made between Vm and point B on selected systems having reversible Type II isotherms. Results confirm that satisfactory agreement is not obtained unless the BET equation is applied over a range of the isotherm which includes Point B.

Assuming point B to represent the true monolayer capacity, there seems little justification for the continued use of the BET equation.

319. SLAWSON, VIDA and SALWIN, HAROLD
Relationship of moisture-vapor pressure to moisture content of dehydrated foods. Abstract of paper presented at 18th Annual Meeting of the Institute of Food Technologists, Chicago, Ill. Food Technol. 12, 1958.

Inasmuch as moisture-vapor pressure is a critical factor in stability of dehydrated precooked meals for specialized military feeding, isotherms showing the relationship of moisture-vapor (or relative humidity) to moisture content were determined. The method which yielded the most data per hour of laboratory manipulation was equilibration in atmospheres of known relative humidity. This was the method used for determining isotherms of a variety of dehydrated precooked foods at 40°F, 72°F, and 100°F. Some of the relative humidities read from isotherms were compared with values obtained by direct manometer measurement or with an electric hygrometer. The isotherms provided a reliable basis for computing moisture transfer among the components of mixtures of foods.

320. SMITH, SHERMAN E.
The sorption of water vapor by high polymers. J. Am. Chem. Soc. 69:646-651, 1947.

A method for the graphic analysis of data on the sorption of water vapor by high polymers is presented. The method subdivides the weight fraction of sorbed water into a bound and a normally condensed fraction. It is shown that hysteresis in the sorption isotherm is a consequence of variation in the fraction of bound water present in the adsorption and desorption processes, the bound fraction being

always larger on desorption than on adsorption. A mechanism for the development of hysteresis is suggested. Conditions for the development of hysteresis are: (1) an enlargement of the sorptive surface as a consequence of swelling and (2) the presence of rigid structural elements in the polymer having dimensions relatively large compared to those of the sorbate molecules. The method is compared and contrasted with that of Brunauer, Emmett, and Teller.

321. SOKOLOVSKY, A.
Effect of humidity on hygroscopic properties of sugars and caramel. Ind. Eng. Chem. 29:1422-1423,1937.

The hygroscopicity has been investigated of saccharose, maltose, lactose, dextrose, levulose, galactose, and caramel made from saccharose and treacle with the addition of various sugars at relative humidities of 43, 62.7, 81.8, and 88.8%. The experiments were made at 25%C and lasted for 60-75 days. These experiments showed that, when the specimens were kept a certain length of time, the greatest hygroscopicity was exhibited by levulose and least by lactose. After crystalline sugars absorbed 16-18% moisture, they became liquids. Caramel is highly hygroscopic. The hygroscopicity of caramel is higher than that of its different ingredients.

322. SORGER-DOMENIGG, HEINZ, CUENDET, L. S., CHRISTENSEN, C. M. and GEDDES, W. F.
Grain storage studies. XVII. Effect of mold growth during temporary exposure of wheat to high moisture contents upon the development of germ damage and other indices of deterioration during subsequent storage. Cereal Chem. 32:270-285, 1955.

Surface-disinfected and mold-inoculated samples taken from a lot of sound hard red spring wheat were stored at room temperature and approximately 14% moisture after being held at 15, 18, and 21% moisture for 5, 10, and 15 days. The series at 21% moisture was also stored at about 13% moisture. High levels of mold infestation markedly increased the losses in viability, development of germ damage, and increases in fat acidity which occurred during temporary storage at elevated moisture contents. During subsequent storage at 14 and 13% moisture the mold counts of the majority of the samples decreased, but germ damage and fat acidity continued to develop, especially in the samples which had been heavily infested with molds. The inoculated samples temporarily exposed to 21% moisture gave large yields of flour of high ash content and poor color. Heavy mold infestation was also associated with poor baking strength and loss in baking quality during storage. Negative correlations were obtained between free fatty acids and loaf volume, germ damage and loaf volume, and logarithm of viability and free fatty acids. Losses in viability preceded the discoloration of the germ and were indicative of incipent damage and poor storage properties.

323. SORGER-DOMENIGG, HEINZ, CUENDET, L. S. and GEDDES, W. F.
Grain storage studies. XX. Relation between viability, fat acidity, germ damage, fluorescence value, and formazan value of commercial wheat samples. Cereal Chem. 32(6):499-506, 1955.

Sixty-eight commercial samples of hard red spring and hard red winter wheats containing from 3 to 60% of germ-damaged kernels and varying in viability from 1 to 95% were analyzed for fat acidity, for the extent of browning as measured by the fluorescence of aqueous extracts, and for dehydrogenase activity (formazan value). Germ damage was positively correlated with fat acidity (r=0.46) and with fluorescence value (r=0.47), and negatively correlated with viability (r=0.49) and with formazan value (r=0.69). Viability was negatively correlated with fat acidity (r=0.92) and fluorescence value (r=0.66) and positively correlated with formazen value (r=0.60).

324. SPENCER, HUGH M.
Laboratory methods for maintaining constant humidity. In International Critical Tables. Vol. 1, pp.67-68, McGraw-Hill, New York, 1926.

A saturated aqueous solution in contact with an excess of a definite solid phase at a given temperature will maintain a constant humidity within any enclosed space around it. A number of salts suitable for this purpose are shown in the charts and tables, together with the % humidity prevailing above their saturated solutions at different temperatures.

325. STADTMAN, EARL R.
Nonenzymatic browning in fruit products. Advances in Food Res. 1:325-372, 1948.

It is the primary aim of this discussion to present a critical review of the literature on browning in fruit products, to emphasize the deficiencies in our current knowledge, and thereby clarify the status of the problem. Browning reactions which are enzyme catalyzed are not considered here. Included in the discussion are the theories of browning, methods of color measurement, the effect of storage temperature, processing temperature, moisture and oxygen on browning, the changes in chemical composition accompanying browning and use of inhibitors to delay browning.

326. STADTMAN, E. R., BARKER, H. A., MRAK, E. M. and MacKINNEY, G.
Storage of dried fruit. Influence of moisture and sulfur dioxide on deterioration of apricots. Ind. Eng. Chem. 38:99-104, 1946.

The edible storage life of dried fruit can be defined as the

time required for the fruit to darken to such an extent that it is no longer generally acceptable. A colorimetric procedure, involving a visual comparison of 50% alcoholic extracts with standardized reference solutions, has been developed for determining the relative degree of darkness of dried fruit samples. By this method the storage life of dried apricots has been determined as a function of the sulfur dioxide level and the moisture content. The storage life is inversely proportional to the initial sulfur dioxide concentration. Sulfur dioxide disappears on storage at a rate which is roughly proportional to the logarithm of the sulfur dioxide concentration. Approximately 65% of the sulfur dioxide initially present is lost during storage life. Under anaerobic storage conditions, the rate of darkening is accelerated by decreasing the moisture content over a range of 40 to 10%, a maximum being reached somewhere between 5 and 10% moisture. In the presence of oxygen, the rate of darkening is increased at high relative to low moisture contents by amounts which vary with the quantity of oxygen available to the fruit.

327. STAMM, ALFRED J.
Surface properties of cellulosic materials. In Wood Chemistry, by Louis E. Wise and Edwin C. Jahn. 2d ed. p.691-814, New York, Reinhold, 1952. (ACS Monograph Series n.97), 1952.

328. STAMM, A. J. and LOUGHBOROUGH, W. K.
Thermodynamics of the swelling of wood. J. Phys. Chem.39:121-132, 1935.

Determinations were made (for the system Sitka sprucewood-water) of the relative vapor pressure-moisture content desorption isotherms. Temperatures varied from room temperature to 100°, and conditions were carefully controlled to minimize the hysteresis effect. Fiber-saturation points decrease linearly with increasing temperatures, and are reduced by 0.1% per 1° rise. Smooth curves were formed (with zero values at the fiber saturation point) for the differential heats of swelling, and free energy and entropy were calculated over the entire sorption range. The relationship between mechanism of sorption and the nature of these curves is discussed. Comparative data on the heats of swelling and free energy and entropy changes for the swelling and solution in H_2O of various (biol.) organic substances and for H2SO4 are included.

329. STEINBERG, M. P.
Development of techniques for the objective description of freeze dehydrated cooked beef. Illinois U., Urbana, Ill. Report No. 9 (Final) (Contract DA 19-129-QM-1332), 15p.1960.

The sedimentation value determination was found to be significantly

related to tenderness of beef. Ferricyanide reducing power was positively correlated with subjective flavor and off-flavor. Volatile carbonyl content was found to increase with storage. The initial improvement in flavor and off-flavor scores with storage at 100°F is discussed.

330. STENBERG, RUSSELL J. and GEDDES, W. F.
Some chemical changes which accompany the browning of canned bread during storage. Cereal Chem. 37:614-622, 1960.

The rate of browning of canned bread, as determined at 600 mμ with a Beckman Model DU spectrophotometer equipped with a reflectance attachment, increased with the temperature of storage. At 25°C there was only very slight browning after 120 days, but at 35°C appreciable browning had occurred at 100 days' storage. At 50° and 75°C browning was progressively much more rapid. No appreciable biochemical changes were noted in bread stored at -15° and 25°C. At 35°C, however, the pH decreased, whereas the total soluble nitrogen, titratable acidity, and amino nitrogen increased in samples stored for 100 days. These biochemical changes were much more marked at 50° and 75°C. Lysine nitrogen decreased with an increase in storage time at 50° and 75°C. Total reducing substances remained essentially constant. Bacteriological tests indicated that these chemical changes were not likely to be due to bacterial action. The brown pigment could not be extracted with water or with a number of organic solvents. Acetylation gave a brown reaction mixture with both white and brown crumb; water then extracted the brown pigment from both samples, yielding solutions of similar absorbance and amino nitrogen content.

331. STEPHENSON, R. M., SANO, T. and HARRIS, P. R.
Storage characteristics of potato granules. Food Technol. 12(11):622-624, 1958.

Storage characteristics of potato granules of 98.6°F for 212 days, and at room temperature and 40°F for 777 days were studied for granules packed in nitrogen, in air in both with butylated hydroxyanisole (BHA). BHA at a concentration of 5 p.p.m. was very effective in preventing the development of rancidity. Nitrogen packing was also effective in this but to a lesser extent. If continued high temperatures of 98.6°F or above may be encountered, moisture contents must not be far above the 6% level. Shelf life of properly protected potato granules can be considered indefinite if storage temperatures are kept at room temperature or below.

332. STEWART, G. F. and KLINE, R. W.
Maillard reaction in egg products. Iowa Agricultural Experiment Station Project Report 1945-1946, 11p. 1946.

Experiments were carried out to determine the nature of the reaction

between reducing sugars and proteins in dried egg whites in order to find a practical means of preventing or retarding this reaction. The changes in the sugars content, amino nitrogen content, color, fluorescence and solubility are noted for storage temperatures of 25°, 40° and 50°C.

333. STILLE, BERND
Limiting value of relative humidity and water content of dried food for microbial attack. Z. Lebensm. Untersuch. Forsch. 88:9-12, 1948.

Points out that the attack of xerophilous microorganisms on dried foods is not dependent on absolute moisture content but on vapor tension. This was demonstrated by evaluating the sporulation of Aspergillus glaucus at various humidities and at temperatures varying from 10-40°. At 30°, growth of molds was controlled by maintaining a R.H. below 75%. Hence, it seemed advisable to determine the moisture content of dried foods at which the vapor tension at 30° was in equilibrium with a 75% R.H. Results are indicated as follows: --potatoes 13.7%, wheat grits 13.4%, spinach 13.7%, green cabbage, 13.2%, savoy cabbage 21.3% potherbs 21%, carrots 20.5%, sauerkraut 33.5%, red cabbage 21%, wheat flour 13.7%, rye flour 13.4%, oat flakes 12%, potato flour 14.2%, noodles 12.5%, "Knäckebrot" 12.9%, cookies 12.3%, zwieback 13.6%, rice 13.6%, white beans 13.3%, peas 13.1%, whole egg powder 10.4%, black tea 11.9%, raw coffee 9.8%, roasted coffee 9.7%, smoking tobacco 19%, cigarettes 17.3%, and cigars 15.5% moisture content.

334. STITT, F.
Moisture equilibrium and the determination of water content of dehydrated foods. In Fundamental Aspects of the Dehydration of Foodstuffs. Society of Chemical Industry, London (New York, Macmillan Press) 1958.

Moisture equilibrium is discussed here in relation to the manner in which water is present in dehydrated foods. The various reference methods proposed for the determination of water content -- vacuum-drying, entrainment distillation and the Fischer volumetric methods -- are examined. The nuclear magnetic resonance and the heat-of-dilution dichromate oxidation methods for measuring moisture are discussed.

335. STOKES, R. H. and ROBINSON, R. A.
Standard solutions for humidity control at 25°C. Ind. Eng. Chem. 41(9):2013, 1949.

Values of the relative vapor pressure of solutions of sulfuric acid, sodium hydroxide, and calcium chloride at 25°C are presented in a form suitable for use as standards of relative humidity in laboratory scale conditioning procedures. Data are also given for the relative

humidities over a number of saturated solutions at 25°C. The figures are based on careful recent determinations of the vapor pressures of sulfuric acid and sodium hydroxide, and on isopiestic measurements.

336. STRASHUN, SUMNER I. and TALBURT, WILLIAM F.
Stabilized orange juice powder. I. Preparation and packaging. Food Technol. 8:40-45, 1954.

New developments in the preparation, flavor stabilization, and packaging of powder from orange juice are described. Effects of pressure, temperature, tray loading and additives, such as corn-sirup solids, pulp or insoluble solids, orange oil and sodium bisulfite, on drying characteristics are given. Rapid drying is obtained with pressures and temperatures higher than those used in freeze drying.

337. SULLIVAN, BETTY
The mechanism of the oxidation and reduction of flour. Osborne Medal Award Address. Cereal Chem. 25 Suppl., 16-31, 1948.

The mechanism of the action of oxidizing and reducing agents on flour was explored by studying the reactions of substances in flour with the different agents. Experimental evidence would seem to justify the conclusion that reducing agents attack the disulfide group of cystine. Oxidizing agents that function as improvers have no effect on cystine or tryptophane. It is highly probable that the compound oxidized contains the sulfhydryl group.

338. _____, NEAR, CLEO and FOLEY, GUY H.
The role of lipids in relation to flour quality. Cereal Chem. 13:318-331, 1936.

Fresh wheat germ fat was not deleterious to the baking quality of a patent flour. Only the unsaturated fatty acids which develop upon aging due to hydrolysis of the triglycerides, and especially the subsequent oxidation products of these unsaturated fatty acids are injurious. The unsaturated acids do not do much harm to baking quality until they become oxidized. The oxidized products are peroxides rather than hydroxy acids. Ether extraction injured the baking quality of both strong and weak flours. Flour fat brought the quality of the ether-extracted flour back to normal in every detail but germ fat did not.

339. SUPPLEE, G. C.
Humidity equilibria of milk powders. J. Dairy Sci. 9:50-61, 1926.

Six samples of milk powder were studied for equilibrium vapor pressures at humidities from 10 to 80% at 25°C. At humidities above

50% the initial moisture absorption is very rapid, and at humidities between 50 and 70% this initial absorption is not retained by the powder. When the maximum is reached a dehydration process begins and extends over a period of months before equilibrium is established at a lower level. The dehydration results obtained after milk powder had been subjected to a relatively high moisture content for a period of three weeks show a different moisture retention at the various humidities than was shown during hydration. The absorptive properties of milk powder were found to be altered by excessive heating and previous saturation. The absorptive ability also decreases with increased fat content and correspondingly lower protein content.

340. SWANSON, C. O.
Some factors involved in damage to wheat quality. Cereal Chem. 11:173-199, 1934.

Mold growth in stored wheat is closely related to moisture and temperature. Wheat stored at 60°F or lower showed very little mold growth when the moisture was 20% and none when it was 18%. At 95°F mold growth was observed at 14% moisture. Mold growth may be inhibited by the entire exclusion of air. Mold growth may also be inhibited by the presence of poisons. Neither of these prevent injury to quality. The length of time during which the factors of high moisture and temperature operate are important. One of the best measures for the extent of damage in wheat is the determination of the amount of acidity which has developed in the wheat fat. The development of this rancidity is related to the air supply. It will not develop in the entire exclusion of air. Sugar was not increased until the moisture was above 18%. The diastatic activity was not increased by high moisture.

341. SWARTHOUT, D. M., JOHNSON, R. A. and de WITTE, S.
Effect of moisture and antioxidant treatment of shelled English walnuts. Food Technol. 12(11):599-601, 1958.

Absorption of oxygen from the headspace air in sealed cans containing shelled walnuts was used to compare the efficiency of the two antioxidant formulations used in this experiment and to compare treated and untreated shelled walnuts. The butylated hydroxyanisole and butylated hydroxytoluene formulation reduced the oxygen absorbed by about one-third. The butylated hydroxyanisole and propyl gallate formulation reduced it by about one-half. The oxygen abosrption increased as the moisture increased. The rate of free fatty acid increased as the moisture increased and was not affected by either antioxidant formula.

342. TALBURT, WILLIAM F., HENDEL, CARL E. and LEGAULT, R. R.
Desiccating in the package. Food Eng. 26(4):79-81, 194, 197, 1954.

The authors describe the water-vapor capacities and other properties of some available laboratory and industrial desiccants which are suitable for use as in-package desiccants with dehydrated food. They include calcined lime, calcium chloride, silica gel, alumina and montmorillonite. Some types of packages which are used to contain these desiccants are evaluated.

343. TAPPEL, A. L. CONROY, A., EMERSON, M. R., REGIER, L. W. and STEWART, G. F.
Freeze-dried meat. I. Preparation and properties. Food Technol. 9:401-405, 1955.

Pieces of beef have been successfully dehydrated by freeze-drying. The rate of freeze-drying is low because of the low thermal conductivity of the dried meat. The resulting freeze-dried beef is pink in color and very porous in structure. It rehydrates readily to give a product having all the essential properties of fresh meat.

Observations on the freeze-drying of serving-size pieces of a wide variety of meat, fish, and poultry are reported.

344. TAPPEL, A. L.
Freeze-dried meat. II. The mechanism of oxidative deterioration of freeze-dried beef. Food Res. 21:195-206, 1956.

Among other findings in the investigation it was reported that if freeze-dried beef is stored in inert atmospheres or at high vacuum, main oxidative deterioration does not occur. However, such storage does not prevent the oxidation of myoglobin in the freeze-dried meat. (From Nat. Agric. Lib., Library list no. 77, 1963)

345. TAPPEL, A. L., MARTIN, RUTH and PLOCHER, ESTHER
Freeze-dried meat. V. Preparation, properties, and storage stability of precooked freeze-dried meats, poultry, and seafoods. Food Technol. 11(11):599-603, 1957.

Many precooked freeze-dried foods were investigated (beef, pork, veal, lamb, chicken, turkey, salmon, oysters, shrimp, and tuna). Two detailed tables supplement descriptive material in presentation of conditions and results of the study. (From Nat. Agric. Lib., Library list no. 77, 1963)

346. TAPPEL, A. L.
Spectral studies of the pigments of cooked cured meats. Food Res. 22:479-482, 1957.

The cured meat pigment was characterized as a denatured globin nitric oxide hemochrome by direct reflectance spectra and stepwise formation. The spectra of the cured meat pigment have a band in the 480 mμ region - which is unusual for hemochromes.

347. TARR, H. L. A.
Cause of browning of certain heat-processed fish products. Fish. Res. Bd., Canad. Pro. Reps. Pac. Stas. 92:23-24, 1952.

From experiments conducted at the Vancouver Station and reported in Progress Reports No. 74, 1948, the discoloration or browning of certain white-fleshed fish during heating...

348. _____
Fish muscle riboside hydrolase. Biochem. J. 59:386-391, 1955.

A method of preparation of crude riboside hydrolase enzymes from muscles of certain marine fish is described. Crude preparations contained 2 (and occasionally 3) proteins as judged by zone electrophoresis, while purified preparations showed a single zone. Purified preparations contained two distinct enzymes, a non-specific riboside hydrolase and a specific inosine hydrolase. These enzymes were not separated. It is concluded that these enzymes are true ribose hydrolases and not phosphorylases. The enzyme preparations withstood freeze-drying and were active even at 55°.

349. _____
The Maillard reaction in fish products. J. Fisheries Res. Board Can. 8:74, 1950.

350. _____
Ribose and the Maillard reaction in fish muscle, Nature 171:344-345, 1953.

Moist fish flesh usually becomes brown during exposure to high temperatures due to reactions of the Maillard type. Muscles of halibut, which browns very slightly on heating at 120°C for 1 hour, was compared to that of lingcod, which browns markedly on heating. The results indicate that ribose is the sugar essential for these reactions.

351. TAYLOR, A. A.
Determination of moisture equilibria in dehydrated foods. Food Technol. 15:536-540, 1961.

A method of evaluating the relations between equilibrium relative humidity (ERH) and moisture content by vapor-pressure measurement has been used to give data on dehydrated foods. The technique is rapid and allows several determinations to be carried out on the same sample at various moisture levels. The method also has potential application as a rapid moisture-determination method giving results after observation of 1 hour. ERH is much more indicative of the behavior of the food with respect to its moisture than is the moisture content. Data for a variety of accelerated freeze-dried foods have been obtained that are applicable to dehydration and storage problems and have indicated the the apparatus could be very suitable for further study of the behavior of water in dried foods.

352. TESSEM, B. M. and HUGHES, F. J.
Description and test evaluation of the Honeywell relative humidity flour moisture meter. Cereal Science Today 10(2):50-52, 1965.

This paper describes an electronic instrument which measures the equilibrium relative humidity (or vapor pressure) of flour and presents data comparing the meter measurements with those determined by the standard oven-drying method.

353. TEUNISSON, DOROTHEA J.
Influence of storage without aeration on the microbial population of rough rice. Cereal Chem. 31:462-474, 1954.

Combine-harvested rice, air-dried to 14.3% moisture or less, contained moderate to large numbers of molds, aerobic bacteria, and anaerobic organisms; low to moderate numbers of actinomycetes; and relatively few yeasts.

Rice with 18 to 20% moisture, sealed in a glass-lined bin for 7 months in one trial and 34 days in another, became sour. Some molds survived but did not increase; aerobic bacteria survived or decreased in numbers; the facultative anaerobic organisms markedly increased; and the yeasts increased tremendously in most of the layers of the piles of rice. There was a loss in seed viability. Critical heating of the rice did not occur.

Other lots with 21.5 to 32.4% moisture, stored in sealed containers in the laboratory, showed the same general changes except that the aerobic organisms often increased.

354. THOMAS, B.
Die Trocknung von Mehl zur Erhöhung seiner Haltbarkeit. Z. ges. Getreidew. 27:7-12, 1940. (Drying flour to increase its keeping quality)

The storage stability of flour with commercial humidity in air-tight cans is limited. Therefore, flour which has been dried in vacuum to a low water content has storage stability and can be stored for 22 years without impairment to its baking properties. It proved to be capable of resistance to the effects of unfavorably high temperatures.

355. TUITE, J. and FOSTER, G. H.
Effect of artificial drying on the hygroscopic properties of maize. Cereal Chem. 40:630-637, 1963.

The equilibrium moisture content (EMC) and equilibrium relative humidity (ERH) of shelled maize dried at varying temperatures in a pilot dryer and in the laboratory is reported and discussed. EMC decreased and ERH increased with increase of drying temperature >140°F, and neither was significantly affected by differences in air-flow rates, drying method or initial maize moisture. Determinations of both moisture content and ERH may be useful in indicating previous drying history of maize samples and in the evaluation of drying methods. Because of its higher ERH, artificially dried maize should be stored at moisture levels from 0.5 to 1.0% lower than naturally dried maize to prevent mould development.

356. U. S. AGRICULTURAL RESEARCH ADMINISTRATION. COMMITTEE ON DEHYDRATION OF MEAT.

Meat dehydration, Washington, 1944. U. S. Dept. of Agric. Circular No. 706, 1944.

357. U. S. BUREAU OF AGRICULTURAL AND INDUSTRIAL CHEMISTRY.
Vegetable and fruit dehydration, a manual for plant operators, U. S. Dept. of Agric. Misc. Pub. 540, 218p. 1944.

The present publication is based on the results of both earlier and more recent work and is designed to serve as a manual for commercial operators. (From the Introduction)

358. U. S. DEPARTMENT OF AGRICULTURE.
Air-oven and water-oven methods specified in the official grain standards of the United States for determining the moisture content of grain. Service and Regulatory Announcement No. 147 (rev. 1941).

359. VOLKOV, K. P. and SAVOSTIANOV, E. O.
Vapor pressure of a saturated sucrose solution at low temperatures. Univ. état de Kiev, Bull. Sci. rec. chim. 3:103-119, 1937.

The vapor pressures of saturated sucrose solutions were measured by the method of R. Helmholtz. For the interval investigated (13.7-43°) the vapor-pressure curve follows $P = G\text{-}(T - \lambda)50/T$ when $\lambda = 75.62$ and $\log G = 7.65013$. (CA 33 23954)

360. VON LOESECKE, H. W.
Drying and dehydration. 2d ed. New York, Reinhold, 1955.

361. WAGER, H. G.
The browning reaction in dehydrated carrot and potato: its initiation and the separation and partial characterization of an intermediate from dehydrated carrot. J. Sci. Food Agr. 6:57-64, 1955.

362. WANG, H., AUERBACH, E., BATES, VIRGINIA, DOTY, D. M. and KRAYBILL, H. R.
A histological and histochemical study of beef dehydration. IV. Characteristics of muscle tissues dehydrated by freeze-drying techniques. Food Res. 19:543-556, 1954.

Freeze-dried samples of beef muscle revealed a rate of moisture removal that was uniform and significantly faster than in samples dehydrated by warm-air methods. Pre-frozen freeze-dried tissues showed no change in total volume of tissue, no sign of denaturation of muscle fiber protein, and presence of a pore system which thoroughly interpolated dried muscle fibers. All freeze-dried samples rehydrated to 85-90% of original moisture content and their muscle fibers returned to 89-98% of their original diameter. A limited degree of potassium displacement was found on rehydration. Oven-dried partially lyophylized samples rehydrated to a significantly higher level than was achieved by dehydration at 65° or 75°C without freeze-drying.

363. WARD, ALAN GORDON
The nature of the forces between water and the macromolecular constituents of food. In Recent Advances in Food Science - 3, edited by James Muil Leitch and Douglas N. Rhodes, London, Butterworths, pp.207-214, 1963.

364. WESTON, W. J. and MORRIS, H. J.
Hygroscopic equilibria of dry beans. Food Technol.8(8):353-355, 1954.

Equilibrium moisture values are reported for seven varieties

of beans stored at 25°C in relative humidities in the range from 11 to 75%. Equilibrium moisture values were not obtained for the relative humidity range from 80 to 98% because of the development of mold growth. The time required for mold growth to become visible together with the moisture contents at these times is given for these humidities. There were no significant varietal differences in equilibrium moisture values. Varietal differences were observed, however, in the rates of change in moisture contents when beans were stored at high humidities.

365. WHISTLER, ROY L., GOATLEY, J. L. and SPENCER, W. W.
Effect of drying on the physical properties and chemical reactivity of corn starch granules. Cereal Chem.36(1):84-90, 1959.

Starch granules dried in air developed a "case-hardened" shell that slowed reagent penetration and reduced granule reactivity. This decrease in reactivity exceeds the compensating effect of increased area due to cavitation and, hence, reduced total granule reactivity.

Starches air-dried at 45°C to different moisture levels and with different degrees of cavitation showed small differences in gelatinization temperatures or viscometric properties. However, as moisture content was lowered, these starches showed decreased reactivity to oxidation, sulfation, and acetylation, although the extent of cavitation was increased. In oxidation and sulfation reactions, lyophilized starch reacted much faster than air-dried starches.

Electron microscopic observations of sections of starch granules soaked in mercuric chloride showed more rapid salt penetration into lyophilized starch than into a commercial air-dried starch.

366. WHITTIER, E. O. and GOULD, S. P.
Vapor pressures of saturated equilibrated solutions of lactose, sucrose, glucose, and galactose. Ind. Eng. Chem. 22:77-78, 1930.

The vapor pressures of saturated equilibrated solutions of sucrose, glucose, galactose, and lactose have been determined at 25°C. These values indicate that the hygroscopic tendencies of these sugars differ, decreasing in the order listed. Calculated values have been obtained for the percentage of atmospheric humidity with which each saturated sugar solution would be in vapor pressure equilibrium. It is suggested that lactose might possibly be substituted in part for sucrose or glucose in confectioners' products in which the hygroscopic tendencies of these sugars are objectionable.

367. WILSON, G. D., WORLAND, MARIE C. and LANDMANN, W. A.
Behavior of water phases in freeze drying. American Meat Institute Foundation. Report No. 9 (Final) (Contract DA 19-129-QM-1347) 26 December 1958 - 19 March 1961.

Final report on water frozen in beef, pork and pork with 2% NaCl; effects of temperature and heat denaturation. Freeze dried surface area. Heats of rehydration. Changes in water holding capacity of beef. Methods outlined.

368. WILSON, ROBERT H., AMBROSE, ANTHONY M., De EDS, FLOYD, DUTTON, HERBERT J. and BAILEY, GLEN F.
The content and biological availability of carotene in raw and dehydrated carrots and other vegetables. Arch. Biochem. 10:131-140, 1946.

369. WILSON, ROBERT E.
Humidity control by means of sulfuric acid solutions, with critical compilation of vapor pressure data. J. Ind. Eng. Chem. 13:326-331, 1921.

Vapor pressure data of sulfuric acid solutions are presented. Recommended methods of determining humidity equilibria of any substance at given temperatures are described.

370. WILSON, ROBERT E. and FUWA, TYLER
Humidity equilibria of various common substances. J. Ind. Eng. Chem. 14(10):913-918, 1922.

The following paper is intended to collect for reference, in a single article, data on the humidity equilibria of various common substances.

The paper first discusses the various types of humidity equilibrium curves. Curves are also given for various substances arranged in groups of related materials, as follows: natural textile fibers, artificial textile fibers, pulp and paper fibers, foodstuffs, other organic colloids, absorbents, various forms of carbon, and finely divided inorganic solids.

If the relative humidity is kept constant, there is surprisingly little change in the equilibrium moisture content of most substances over the ordinary range of indoor temperatures. There is need, however, of further work on the effect of temperature changes in connection with hot air drying.

371. WINDSOR, W. E., SOBEL, F., MORRIS, V. B. JR. and HOOPER, M. V. Critical relative humidities of some salts. Rev. Sci. Instr. 24:334, 1953.

The critical relative humidity of 20 salts at 25°C have been determined by means of an electric hygrometer and are tabulated.

372. WINK, W. A.
Determining moisture equilibrium curves of hygroscopic materials. Ind. Eng. Chem., Anal. Ed. 18:251-252, 1946.

A procedure for obtaining sorption data of any given material which consists of weighing the specimen suspended in a closed vessel in which the relative humidity is controlled by a saturated salt solution is described. The equilibrium relative humidities for a number of saturated salt solutions at 73°, 86° and 100°F are given.

373. _____ and SEARS, G. R.
Instrumentation studies. LVII. Equilibrium relative humidities above saturated salt solutions at various temperatures. Trans. Amer. Paper and Pulp Inst. 33:96A-99A, 1950.

This report presents new data for a number of saturated salt solutions employed in maintaining constant relative humidity in essentially moisture-tight enclosures. The equilibrium relative humidity and the vapor pressure of saturated solutions are given for three temperatures - namely, 73, 86, and 100°F. For the readers' convenience, charts showing the dependence of the relative humidity on temperature are presented so that the equilibrium relative humidity over a saturated solution may be obtained for any temperature between room temperature and 100°F.

374. _____
Moisture equilibrium: sorption isotherms offer graphic method of finding relationship between moisture level and equilibrium relative humidity. Mod. Packaging 20(6): 135-138, 162, 164, 1947.

A procedure for obtaining sorption data of any given material which consists of weighing the specimen suspended in a closed vessel in which the relative humidity is controlled by a saturated salt solution is described. The equilibrium relative humidities for a number of saturated salt solutions at 73°, 86° and 100°F are given

375. WONG, FRANCIS, F., DIETRICH, WILLIAM C., HARRIS, JEAN G. and LINDQUIST, F. E.
Effect of temperature and moisture on storage stability of vacuum-dried tomato juice powder. Food Technol. 10:96-100, 1956.

The stability of a vacuum-dried tomato-juice powder stored at various temperatures under a variety of packaging conditions has been investigated by analytical and subjective-appraisal methods. In-package desiccation used with an inert atmosphere appears to be the most favorable packaging procedure. Air-packing is less desirable because of adverse flavor and color changes. Nonenzymatic browning and ascorbic acid content are most affected by increased moisture and higher storage temperatures. Visible color changes have not been excessive but appear to be most evident in air-packed material. A small consumer-type panel survey on a limited number of samples stored for one year indicates a high degree of acceptability for the product.

376. WONG, FRANCIS F. and BOHART, GEORGE, S.
Observations on the color of vacuum-dried tomato juice powder during storage. Food Technol. 11:293-296, 1957.

Observations on the color stability of vacuum-dried tomato-juice powder indicate that overall color differences from control samples are most marked in air-packed materials. Lycopene changes are not affected by in-package desiccation but show progressive deterioration in air-packed samples. An apparent recovery of the lycopene level is indicated in vacuum- and nitrogen-packed tomato-juice powder after prolonged storage.

377. WOODROOF, J. G.
Long-term storage of operational rations. Univ. of Georgia, Georgia Experiment Station, Report No. 30, Final. 203p, 24 June 1953 - 16 August 1958 (Contract DA44-109-QM-1511)

Tests on 45 food products stored for up to 5 years at various storage temperatures and relative humidities were made at six-month intervals. Examinations included sensory evaluations, physical and chemical changes in the products, and the condition of the containers. The shelf life of the ration items varied from one to many years due to the nature of the product and the method of packaging. The shelf life of the individual products varied from six-months to an excess of five years due to storage temperature. The detailed findings for each of the products are given.

378. _____ and CECIL, S. R.
Nuts: Better kept - better candy. Food Eng. 23(11):129-131, 148, 150, 1951.

Storing of nuts under refrigeration preserves color and flavor, effectively retards rancidity, prevents infestation...Shelling shortens shelf life.

379. WUHRMANN, J. J., SIMONE, MARION AND CHICHESTER, C. O.
The storage stability of freeze-dried soup mixes. Food Technol. 13(1):36-40, 1959.

The relative storage stability of freeze-dried soup mixes vs. dehydrated soup mixes was determined by a sensory panel. Freshly prepared soup mixes made from freeze-dried vegetables were judged higher in quality with less off-flavor than those prepared from dehydrated vegetables. The effect of storage at elevated temperatures increased the off-flavor scores of both types of mixes similarly. Initial flavor differences were maintained throughout the three-month storage period. The effect of packing under nitrogen was to first decrease the off-flavor scores, but as storage time progressed the effect was reversed.

Dehydration rates of freeze-drying for various vegetables are presented. Rehydration rates were significantly faster and the water uptake ratios were higher for freeze-dried than for conventionally dehydrated vegetables.

380. ZETTLEMOYER, A. C.
Adsorption as a research tool. Trans. N. Y. Acad. Sci. II, 10(2):56-58, 1947.

Gas adsorption techniques are used today to study adsorbents, catalysts, pigments, and any solid for which interaction with gases or liquids is the important phenomena. The Brunauer, Emmett, Teller method is used for determining the surface area of a solid with considerable precision and accuracy. Some of the work in the area adsorption at the Lehigh Gas Adsorption Laboratory is mentioned.

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13. ABSTRACT

A bibliography with abstracts of 380 references on moisture equilibrium in relation to the chemical stability of dehydrated foods. Author and detailed subject indexes are provided.

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