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Inspiration and Information

Making Libraries work for Food Technologists

By Barbara Johnston

Division of Food Research, CSIRO, North Ryde, N.S.W.

Where do scientists and technologists get their productive ideas? An improved method or an idea for a new product may seem sometimes to come from a sudden insight, but even such flashes of inspiration, as well as innovations worked out more slowly, are based on all the information on the subject that the technologist has been able to gather, subconsciously or deliberately, from the sources available to him, such as his original training, conversation with colleagues, and what he has read in books, journals, patent specifications, and catalogues.

Survey of Industry

Schaefler and Melton (1970) carried out a survey for the Royal Melbourne Institute of Technology among 1500 companies in Victoria, with the object of finding out their information needs and practices. The majority of firms reported that their new ideas for methods and products, other than those from associate companies in Australia, were derived most often from books and magazines. Even 62 of the 237 companies that did not subscribe to any journals still gave this reply. Other sources mentioned frequently in answers to the questionnaire were suggestions by customers, overseas associates, suppliers of materials and equipment, trade and professional associations, and to a lesser extent consultants and government instrumentalities including CSIRO.

This survey included 98 Victorian companies in the food, beverage, and tobacco industries, and 43 of these reported that they had one or more members of staff engaged in research and development or design; the total number was 115 people in the 43 firms. Fifty-seven firms had the benefit of research or development facilities provided by associates in Australia, 31 had facilities provided by associates overseas, and 24 had no research or development facilities available to them. Seventy-two of the 98 companies had one or more members of staff with tertiary training.

In spite of the help that companies in the food, beverage, and tobacco industries acknowledge that they receive from publications, 40 companies questioned in the survey replied that they had fewer than 50 books in their library, and few of them subscribed to more than 20 periodicals. Only two employed a qualified librarian and 58 reported that the running of their library was informal.

In a survey which he undertook for the Swinburne College of Technology, Hawthorn, Vic., Cohen (1969) found that among companies having factories in Hawthorn (they were not food manufacturers), few consulted publications. They used the staff of firms who supplied their materials as their main sources of information for solving technical problems. He attributed this to lack of useful libraries in the manufacturing companies and lack of knowledge of where technical literature was available to them.

Sources of Information

As the Division of Food Research has libraries with collections dealing with most aspects of food, and experience in their use for a wide range of activities, it was felt that some description of the publications that have been found most helpful would be of benefit to other organizations wishing to improve their access to the literature in this large and complex area, or to food technologists entering a field that may be new to them.

Books

Since university courses in food science and technology were established in industrialized countries in recent years, many more books on these subjects have been published and the number of journals has increased greatly. The purchase of books is now easier, since leading publishers hold stocks in Australia and long delays while the books are being brought in from overseas are less frequent. Not all the books and periodicals on food are of a high standard, and many of those useful to workers in this field were written for use in related disciplines such as chemistry, microbiology, chemical engineering, and agriculture.

Periodicals

Although books are invaluable for finding basic information quickly and in the training of staff, periodicals are essential for finding out the latest ideas and for obtaining more detailed information on any subject. Well over 1000 periodicals dealing with food are now published throughout the world. Besides those devoted to their own specialities such as *Cereal Chemistry*, *Journal of Dairy Science*, or *Quick Frozen Foods*, most companies will need to subscribe to some journals which give a broader view of the food industries for news of people and companies, advances in equipment and materials on the market, and for informative articles on basic food science and its applications. Some well-known examples are *Food Manufacture*, *Food Technology*, *Journal of Food Science*, and *Food Technology in Australia*. A list of recommended books, periodicals, and pamphlets has been prepared, and may be obtained by writing to the author.

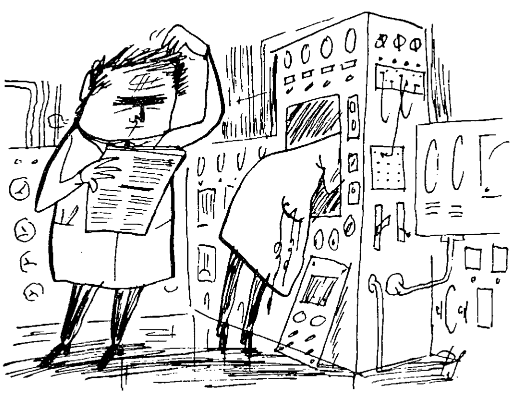
To find out what new papers on a particular subject have appeared in the periodicals, various finding publications can be used. These are of different types and the simplest is *Current Contents* which reproduces by photolithography the tables of contents of a huge number of periodicals each week without comment or amplification. This weekly is published in several editions, of which *Current Contents: Agriculture, Food, and Veterinary Science* is the most useful for readers in the food industry.

Indexes

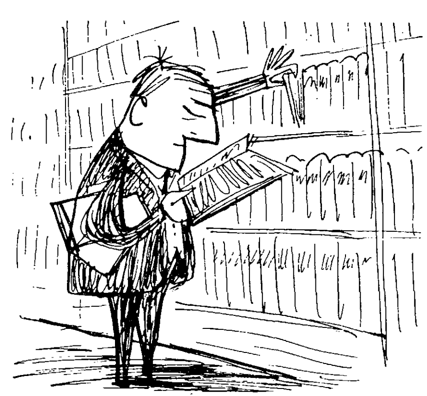
Indexes which list new articles under subject headings are quicker to use, although they may be less comprehensive. They include *British Technology Index* covering about 15 English food journals and a further 30 likely to contain articles of interest, and *Biological and Agricultural Index* which covers about 12 useful journals. These both produce an annual cumulative volume so that articles appearing in earlier years can be easily found. *Australian Science Index* lists all articles in *Australian Food Manufacturer and Distributor*, *Food Technology in Australia*, and other local journals devoted to chemistry, engineering, agriculture, and fisheries. Its monthly author and subject indexes are cumulated in the December issue each year.

Abstracts

Abstracting journals are even more useful



Scientist with problem.



Literature selected.

than indexes because they summarize information given in articles appearing in numerous periodicals. The leading example in English is undoubtedly *Chemical Abstracts* which gives splendid coverage of the world's literature in analytical methods, biochemistry, microbiology, foods, and chemical engineering, but as the subscription is now $US2400.00 per annum it can only be taken by large libraries. *Analytical Abstracts*, published by the Society for Analytical Chemistry, is useful for collections that do not have *Chemical Abstracts. Nutrition Abstracts and Reviews*, *Horticultural Abstracts* as a key to the literature of fruit and vegetable storage, *Bulletin of the International Institute of Refrigeration*, and *Packaging Abstracts* are also valuable sources of information.

For 12 years after the demise of *Food Science Abstracts* in 1957 there was no comprehensive publication in English that covered the whole area of food technology and the sciences on which it is based. In 1969, however, the International Food Information Service launched *Food Science and Technology Abstracts*. It is a truly international project as most of the abstracting and editing is carried out at the Commonwealth Bureau of Dairy Science, at Shinfield near Reading in England; the Institute of Food Technologists in USA and PUDOC in Wageningen in the Netherlands also cooperate, and the printing and indexing are carried out with the aid of a computer in Western Germany.

In 1971 *Food Science and Technology Abstracts* included summaries of about 16,500 papers from 1200 journals, and patents of 20 countries, besides lists of new books. At £UK100 per year this abstracting periodical is a sound investment for any establishment dealing with food. Use of the computer makes possible the inclusion in each monthly issue of author and detailed subject indexes and their cumulation later to give annual indexes, and from the same data base other services can be supplied to order. These include current awareness searches of the new issues for information on particular questions, ahead of publication. These searches can be ordered on a subscription basis from £UK10 per annum for one topic. Retrospective searches can also be ordered. By scanning the records held on magnetic tapes with a computer, references can be selected to give a state-of-the-art survey on any topic, which can be presented to the inquirer as a list of articles, or abstracts thereof, or photographic copies of the full articles if desired. Prices for these searches may be as low as £UK5 for each volume scanned. The results of some literature searches of this kind have been printed and are for sale as *Food Annotated Bibliographies*; examples are 'Microwaves in Food Processing' (79 references, price £UK1), and 'Texture Analysis of Foods' (246 references, price £UK4.50). Photocopies of the original periodical articles are sold at seven pence per page and magnetic tapes for searching by computer can be supplied.

Solution found.

All these services indicate what has been written on any subject, and they should be consulted by a food technologist embarking on a new line of work or faced with a problem on which he needs information. If they are not in his own library it is worth the time and effort to visit a larger collection. The use of abstracting and indexing periodicals for a literature search will enable a list of relevant articles to be compiled, and the periodicals in which they occur can be traced through union catalogues that record the holdings of numerous libraries. The most comprehensive is *Scientific Serials in Australian Libraries*, compiled by CSIRO, but small libraries may prefer to buy less expensive smaller lists, e.g. *List of Periodicals in Special Libraries in New South Wales*. The locations of specific books may be found out by writing, or sending a teleprint, to the National Library of Australia, Union Catalogue Section, where the holdings of university and large public and special libraries are recorded on cards.

4 FISHLER, M.; MONSELISE, ... **phon (2-chloroethylphosphonic ac... elopment of Shamouti orange frui...** *Agricultural Research* (1971) **21**(2) ... brew University of Jerusalem, Re... Detached and attached green ... e dipped in ethephon solutions ... ing the season. The degreening ... end on the amount of active mat... concentration. The duration of ... the application of one drop was ... homogeneous colour change all o... ver storage temperature of 25° as ... e better results if applied during t... tment. Both pre-harvest and ... a degreening effect, but fruits tr... season on the tree changed colou... regreened later. Ethephon ... rnal ripening, but caused fruit a... lied at high concentrations. Eth... mising on the tree at medium co... 0 p.p.m.) a few weeks before natu...

5 MANAGO, M.; OGAKI, C. ... **storage treatment of Unshiu oran... re-cooling on the peel.]** *Bulletin ... ticultural Experiment Station* (19... en, 16 ref., 3 pl., 1 fig.] Ninomi... In the peel of pre-cooled fruit t... spiration rates and water conte... stomata were less open than in un... e was also affected by pre-cooli... and higher electrical conducti... ng storage was 2% less in the pr... ty was also reduced. When the p... blue mould the extent of the r... rsely related to the K content o... decayed area was small and the ... peel of the pre-cooled fruit.

MONZINI, A. **[Research ... vità sperimentale 1970.** *Ann... imentale per la Valorizzazione ... lotti Agricoli, Milano* (1970) **1** 9-... Research is in progress on le... aging.

RAM, H. B.; SRIVASTAVA, R. ... H, L. **Effect of plant growth ... ge behaviour and post harvest ... (Citrus aurantifolia Swingle).** ... re (1970) **2**(1) 51-56 [En, 5 r... Preservation and Canning In... India. Kagzi limes were treated with M... 0 or 500 p.p.m. before storage at ... 35° C) and low temperature (4- ...

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Some effects of rumen ciliate protozoa in cattle given restricted amounts of a barley diet By I. G. WHITELAW, J. MARGARET EADIE, S.O. MANN and R.S. REID 425-437

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...rticultural Science (197... USDA, Pomona, Califor... es emanating from intac... by gas chromatography... he longer the oranges w... he rate of volatile proc... he fruits were returned ... dominant volatile dur... hanol production progr... fell when the oranges ... e of acetaldehyde pro... e, rose markedly to a m... s were returned to air, a... rate of methanol pro...

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cid odor appeared in 90-120 days. As the P.O.V. and refractive index increased, the I no. decreased.

32844j Iron-tannin reactions in pickles. Preventive control system for vinegar. Andreotti, Rodolfo; Tomasicchio, Massimo; Castelvetri, Franco (Italy). *Ind. Conserve* 1971, 46(4), 265-8 (Ital). Pyrogallolic tannin in vinegar reacts with Fe in cans of pickled vegetables, forming blue spots. Treating the vinegar with activated C eliminates or considerably reduces the tannic acid and pyrogallolic tannins, thus preventing spots from forming. N. Coniordos

32845k Effect of gamma irradiation on carotenoid synthesis and color development in tomatoes. Baraldi, D. (Cent. Studi Nucl., Com. Naz. Energ. Nucl., Casaccia Rome, Italy). *Atti Simp. Int. Agrochim.* 1971, 8, 556-62 (Eng). Tomatoes irradiated at 2 different stages of maturity with low doses (150 and 250 krad) and stored at room temp. show a marked decrease in color development. The pigment extn. is carried out with the method of Moore, the gross pigment curves are recorded with a Beckman spectrophotometer, and the sepn. uses thin-layer chromatog. The biosynthesis of lycopene and β-carotene is delayed to a great extent in the irradiated sample for >10 days. Chlorophyll and pheophytin are present in a higher amt. in the irradiated tomatoes; they disappear within 10 days in the control sample, while they are still present in the irradiated sample. Lutein seems not to be affected by the irradn. The delay of ripening in tomatoes is greater when irradn. is made at the green stage of maturity. Radiation acts above all at the ζ-carotene and neurosporene levels. J. Touratier

32846m Erythrosine. Adventitious source of iodide. Vought, R. L.; Brown, F. A.; Wolff, J. (Natl. Inst. Arthritis Metab. Dis., Natl. Inst. Health, Bethesda, Md.). *J. Clin. Endocrinol. Metab.* 1972, 34(4), 747-52 (Eng). Erythrosine (tetraiodofluorescein), an approved food color, can contribute substantially to dietary I intake. An erythrosine-contg. cereal was fed to rats for periods of 3 and 5 weeks. At the end of each expt. $Na^{131}I$ was injected i.p. and the rats were immediately placed in metabolic cages so that urine could be collected. The feces were discarded. The thyroidal uptake of ^{131}I and the protein-bound radioactivity of the serum were both markedly reduced and the non-protein-bound radioactivity was elevated following the feeding of a cereal contg. erythrosine. Urinary ^{131}I was increased in the erythrosine-fed animals and total ^{131}I and urinary I^- were sharply increased. When erythrosine-^{131}I was fed to rats, 25-33% of the ^{131}I was metabolized to iodide. A table listing the I content of both pharmaceuticals and foods is appended. N. R. Stephenson

32847n Use of γ-irradiation to inhibit sprouting in potatoes. I. Extension of shelf life and quality of Bintje potatoes. Baraldi, Delio; Guerrieri, Giovanni; Miuccio, Concetta (Italy). *Ind. Conserve* 1971, 46(4), 269-76 (Ital). Potatoes treated with ...

thioate) as follows: 14 ppm in or on corn fodder and forage; 0.1 (negligible residue) in or on corn grain. William Horwitz

32852k Irradiation of succulent plant raw material. Koval'skaya, L. P. (USSR). *Radiats. Obrab. Pishch. Prod., Dokl. Vses. Nauch.-Tekh. Konf.* 1968 (Pub. 1971), 95-101 (Russ). Edited by Rogachev, V. I. Atomizdat: Moscow, USSR. The doses of γ-irradn. for prolonging stability of fruits and vegetables such as strawberries, raspberries, mazzards, cherries, peaches, apricots, mandarins, oranges, grapes, tomatoes, sweet peppers, and the corn against contamination with microorganisms such as *Aspergillus niger, Penicillium italicum, P. digitatum, Monilia laxa, M. fructigena, Sclerotinia libertiana* [*Sclerotinia sclerotiorum*], *Botrytis cinerea, Alternaria citri, Rhizopus nigricans,* and species of *Mucor, Catenularia, Trichothecium,* and *Fusarium,* including *F. lycopersici,* were detd. The LD levels of irradn. which controlled spores were 200-2000 krad; dose levels to control growth of mycelia ranged from 400 to 2000. Irradiated apples, and pears should be stored at const., low temps. J. Smydzuk

32853m Food additives. Pressure sensitive adhesives. Anon. (Food Drug Adm., Washington, D.C.). *Fed. Regist.* 09 May 1972, 37(90), 9317 (Eng). Tri(mixed mono- and dinonylphenyl) phosphite (not >1% triisopropanolamine) may be used under the Federal Food, Drug, and Cosmetic Act as an antioxidant and(or) stabilizer in the manuf. of pressure-sensitive adhesives for food contact use. William Horwitz

32854n Food additives. Components of paper and paperboard in contact with dry food. Anon. (Food Drug Adm., Washington, D.C.). *Fed. Regist.* 09 May 1972, 37(90), 9317 (Eng). Cf. *CA* 74: 21946f. Modified polyacrylamide resulting from an epichlorohydrin addn. to a condensate of CH_2O-dicyandiamide-diethylenetriamine and which product is then reacted with polyacrylamide and urea to produce a resin with 5.6-6.3% N and a min. viscosity in 10% aq. soln. of 200 centipoises may be used under the Federal Food, Drug, and Cosmetic Act as a dry-strength and pigment-retention-aid agent in paper and paperboard intended for use in contact with dry food. The max. level is 1% of the dry fibers. William Horwitz

32855p Ecological chemistry. XLII. Distribution and transformation of heptachlor-^{14}C in white cabbage and wheat. Weisgerber, I.; Klein, W.; Korte, F. (Inst. Oekol. Chem., Schloss Birlinghoven Siegburg, Ger.). *Chemosphere* 1972, 1(2), 89-94 (Ger). The insecticide heptachlor forms heptachlor epoxide in plant tissues and heptachlor epoxide, 1-hydroxychlordene, 1-hydroxychlordene 2,3-epoxide in soil, as well as other only partially identified metabolites. Using heptachlor-^{14}C, the proper amt. was established for the application of the insecticide to white cabbage and wheat grains. After 4 weeks, the cabbage had taken up 7.1% of the applied amt. The wheat grains had absorbed 2.4% after 3.5 months. The distribution of ...

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library bulletin

Capsaicin. A Rapid Gas-Liquid Chromatographic Determination for Capsaicin in Capsicum Spices. K. T. HARTMAN. *Ibid.*, pp. 543-547.

Caraway Flavor. Effects of pH and Temperature on Volatile Constituents of Caraway. Y. YIN, N. ZARGHAMI, and D. E. HEINZ. *Ibid.*, pp. 531-533.

Cardamom Flavor. Effects of pH and Temperature on Volatile Constituents of Cardamom. C. P. BRENNAND and D. E. HEINZ. *Ibid.*, pp. 533-537.

Cereal Grain Aroma. Headspace Vapors from Cereal Grains. F. W. HOUGEN, M. A. QUILLIAM, and W. A. CURRAN. *Journal of Agricultural and Food Chemistry*, vol. 19, No. 1, January-February, 1971, pp. 182-183.

Citrus Oils. The Analytical Characteristics of Israel Orange Oil and Israel Grapefruit Oil. H. B. BASKER, A. LIFSHITZ, and Y. STEPAK. *Lebensmittel-Wissenschaft und Technologie*, vol. 3, No. 5, 1970, pp. 83-86.

Bacteriological Contamination of Some Citrus Oils during Processing. D. I. MURDOCK and G. I. K. HUNTER. *Journal of Food Science*, vol. 35, No. 5, September-October, 1970, pp. 652-655.

Comparison of Valencia Essential Oil from California, Florida and Israel. A. LIFSHITZ, W. L. STANLEY, and Y. STEPAK. *Ibid.*, pp. 547-548.

Nootkatene from *Citrus sinensis*. I. D. LUND, R. L. COLEMAN, and M. G. MOSHONAS. *Phytochemistry*, vol. 9, November, 1970, pp. 2419-2422. (Orange peel oil.)

Coconut Flavor. Volatile Flavor Components of Coconut Meat. I. M. LIN and W. F. WILKENS. *Journal of Food Science*, vol. 35, No. 5, September-October, 1970, pp. 538-539.

a Practical Lower Limit of Detection. J. I. IVERSON. *Journal of the Association of Official Analytical Chemists*, vol. 53, No. 6, November, 1970, pp. 1214-1223.

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Food Science and Technology Abstracts Vol. 4 (1972) No. 06 6 S 699

6 S 694
[Sequestration of calcium by pork. Effect on water-retention capacity. II.]
Frouin, A.; Scheck, J.
Industries Alimentaires et Agricoles **88** (12) 1707-1714 (1971) [35 ref. Fr]
Following a theoretical discussion of sequestration in relation to the systems calcium-meat and calcium-polyphosphate for different concn. of Ca^{++}, results are given of water retention capacity of pork meat in the presence of variable concn. of calcium and polyphosphates. It is concluded that water retention depends upon calcium content but is exclusively a function of ... Ca^{++} ions are ... face and produce a ... ater retention ... roken by gentle ... by meat is relatively ... e. The action of ... the basis of ... s. Polyphosphates ... ions by

... y of cooling water on ... ultry meat. I.

meat surface had a favourable effect on prolongation of its keeping quality. STI

6 S 697
Radurization of whole eviscerated chicken carcass.
Kiss, I.; Farkas, J.
Acta Alimentaria Academiae Scientiarum Hungaricae **1** (1) 73-86 (1972) [28 ref. En]
[Central Food Res. Inst., Herman Otto ut 15, Budapest II, Hungary]
The influence of various radiation doses on storage life and organoleptic qualities of whole eviscerated chicken carcasses was examined. Eviscerated, whole carcasses, weighing 0.8-0.9 kg were sealed in Saran shrink foil and irradiated with 0.2-0.5 Mrad γ-rays from a ^{60}Co source. Irradiated and non-irradiated foil-packaged carcasses were then stored at 0-4°C. Control samples were stored at -28°C. Irradiation with 0.2-0.5 Mrad extended the keeping quality of chicken carcasses in cold storage 2-3 times i.e. at least for 10-15 days, without a noticeable deterioration in organoleptic quality. Also this radiation treatment was shown to practically eliminate Salmonella infection of the carcasses. AB

6 S 698
Prepared poultry products.

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BRITISH TECHNOLOGY INDEX

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Related Headings—*cont.*
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Life and work of Appert (contd.) *Cann. Pack.*, 39 (Sep 69) p.10
How Appert made cans (contd.) *Tin Print. Box Mkr.*, 45 (Sep 69) p.12

FOOD : Determination of fumigant residues : Gas—Liquid chromatography
Determination of fumigant residues in cereals and other foodstuffs: a multi-detection scheme for gas chromatography of solvent extracts. S.G. Heuser & K.A. Scudamore. *J. Sci. F. Agric.*, 20 (Sep 69) p.566-72. *refs.*

FOOD : Flavouring materials
Related Headings:
CONDIMENTS

FOOD : Freezing : Fluidisation : Equipment
Cold stores: key role in handling technique development? (Frigoscandia) B. Toole. *Storage Handl. Distrib.*, 13 (Sep 69) p.38-9

FOOD, Frozen : Pallets : Transport : Vehicles, Commercial,, Refrigerated
Pallets cut fridge van costs and loading times (Alpine Refrigerated Deliveries Ltd.) *Comm. Veh.*, 43 (Sep 69) p.26-7. *il.*

FOOD, Precooked,, Frozen
New frozen meals firm aims at top end of market (Alveston Kitchens) *Frozen Fds.*, 22 (Sep 69) p.33-4. *il.*

FOOD : Preservation : History
History of food preservation: social background (contd.) V.J.M. Bryant. *Cann. Pack.*, 39 (Sep 69) p.6

FOOD : Processing : Pumps : Air motors
Air pumps in food processing (Neumo Ltd., Peacehaven, Sussex) *Fluid Pwr. Int.*, 34 (Sep 69) p.37-9. *il.*

FOOD : Research,. Great Britain
Food research. A.W. Holmes. *Agriculture*, 76 (Sep 69) p.416-19

FOOD : Transport : Trays; Plastics
Three-way gain (Marks & Spencers Ltd. & Airfix Plastics Ltd.) *Comm. Veh.*, 43 (Sep 69) p.38-9. *il.*

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1237 Good housekeeping is key to good hygiene. L.R.Watson. Australas.Baker 75(1):39-40 Ja'72

1238 Bacterial spoilage in dry red wine and its relationship to malo-lactic fermentation. E.C.Rankine and D.Annette Bridson. Aust.Wine Brewing Spir.Rev.90(3):44, 46, 48, 50 D'71

1239 Nature of colour in red wines. T.C.Somers. 7 refs Fd Technol.Aust.24(1):10-12 Ja'72

1240 Technical advances and probable trends in the use of dairy products in other food industries. R.A.Buchanan. Fd Technol.Aust.24(1):22-5 Ja'72

1241 New dairy foods: a review. E.J.Mann. 134 refs Fd Technol.Aust.24(1):26-30, 32 Ja'72

1242 Development of new dairy foods in Queensland. Ailsa J. Gillies. Aust.J.Dairy Technol.26(4):138-9 D'71

1243 Market milk quality control in Queensland. V.R.Smythe. Aust.J.Dairy Technol.26(4):135-7 D'71

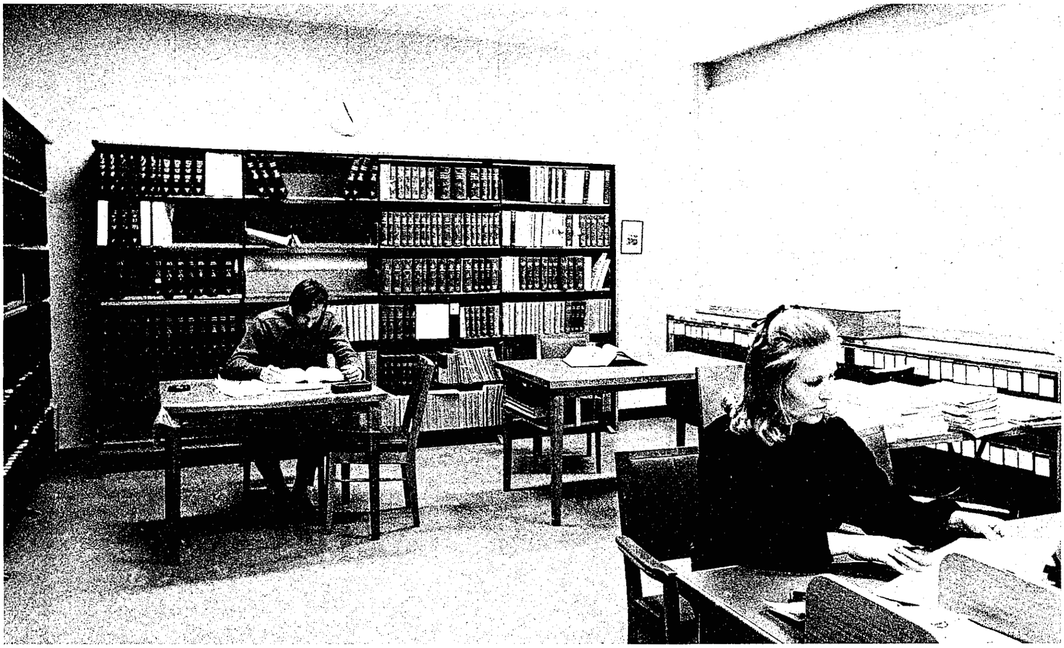
Excerpts from some indexing and abstracting periodicals: 1, *Current Contents*; 2, *Chemical Abstracts*; 3, *Fritsche-D & O Library Bulletin*; 4, *Food Science and Technology Abstracts*; 5, *British Technology Index*; 6, *Australian Science Index.*

State Libraries

One of the objects of the State Libraries in the capital cities is to help local industries, and their reference services are usually prepared to assist inquirers by bringing together literature on particular topics from their large collections, and helping to obtain articles from other libraries or from overseas, as well as by selling photocopies of papers from their journals. In Western Australia, the Commerce and Technology Division of the State Reference Library has an alerting system by which individuals and companies are notified of books or periodical articles added to its stock on subjects known or thought to be of interest to them.

CSIRO Libraries

CSIRO libraries welcome scientific workers from outside the Organization. The services that each can offer depend on space and staff but usually include sale of photocopies of journal articles. The Organization's Food Research Laboratory at North Ryde, N.S.W., has the best general collection on food technology, but the Meat Research Laboratory at Cannon Hill, Qld., and the Dairy Research Laboratory at Highett, Vic., have many works on foods other than those in which they are especially interested. Aids to tracing useful literature that are held in the library of the Meat Research Laboratory include *Bibliography of Agriculture*, *Meat Science Review*, and *Veterinary Bulletin*, in addition to *Chemical Abstracts* and *Food Science and Technology Abstracts*. In the Highett library,



Readers using abstracts and current journals in the library of CSIRO Food Research Laboratory.

Dairy Science Abstracts is invaluable. The Central Library and Information Service at East Melbourne has, in addition to its large collection, a card catalogue of the holdings of all the other CSIRO libraries, including works on order.

Its Information Service receives on magnetic tape weekly indexes to *Chemical Abstracts*, *Physics Abstracts*, *Electrical and Electronics Abstracts*, and *Computer and Control Abstracts* and will send to CSIRO research scientists as a regular service lists of articles on their special interests selected by computer. In 1973 this 'selective dissemination of information' will also be offered to some scientists in universities and industry who may apply through the Royal Australian Chemical Institute. The price will be from $100 a year and subscribers will be limited in the beginning to 50, a number that can be assimilated smoothly into the system, with the possibility of service to much greater numbers later. In order to make the best use of the computer print-out subscribers should have access to the abstracts that are indexed on the magnetic tape.

Other Library Services

The Library and Information Service in Sydney and Melbourne of the ACI Technical Centre, which has a large staff of university graduates and librarians backed by computer and microfilming facilities, is now selling its 'Dial a Library' information service to other organizations at prices that may be more economic than setting up a new library. As well as producing bibliographies and photocopying, it can provide translations and information on the structure and the products of overseas and Australian companies. With the continuing development of its computer-based information retrieval system, it is hoped that current awareness services on selected topics may be offered commercially. Its library is particularly strong in publications on packaging, glass, plastics, building materials, management, marketing, and chemical engineering.

Most libraries will lend only to another library but companies without a librarian can often arrange to borrow through their local municipal lending library, or a professional association. Some research associations offer good bibliographic services to their members. Almost every library will allow a genuine inquirer to consult its books on the premises.

Characteristics of the Progressive Company

In a well-known survey, Carter and Williams (1959) classified companies according to their progressiveness and decided that the characteristics of technically progressive firms included readiness to look beyond the company and to have standards set by the best world practice, willingness to be stimulated by incoming technical information which they sought deliberately, and effective internal communication. The firms they classified as most progressive subscribed to scholarly journals and had the incoming literature scrutinized by technologists capable of recognizing its implications.

An earlier survey in England for the Department of Scientific and Industrial Research (1959) showed that many companies bought the necessary books and journals describing advances in their fields, but were not organized to get the maximum benefit from them: nobody had the responsibility of looking for new ideas and passing them on to the men who could use them; information did not flow. Another study in the Newcastle area in England showed that 31% of unsolicited technical literature sent to firms did not reach any person who could recognize whether or not it was useful.

Allen (1971), of Massachusetts Institute of Technology, at a Seminar on Scientific and Technical Information Policies for Industry arranged by the Organization for Economic Cooperation and Development reported that he had found certain individuals to be 'star' communicators; they read more technical journals, maintained more contacts with informative people outside their companies, and were active in passing on the information they acquired. He called them 'technological gatekeepers' and found them important both for companies needing information, and for those trying to introduce new ideas to them.

A formula for progress in any firm seems to require at least one 'technological gatekeeper' who, in addition to his other work, is charged with the responsibility of collecting and passing on information, and who has access to a good range of original literature and the bibliographic keys to make it usable, preferably in a well-organized library rather than in a random collection.

Acknowledgment

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Taste Panel Techniques

II. A Validating Technique

By A. Howard

Division of Food Research, CSIRO, Cannon Hill, Qld.

This article is based on a talk given to the Brisbane branch of the AIFST on 24 February 1971. It is hoped to produce a Divisional Technical Paper giving in greater detail an analysis of the data that have been briefly treated in Dr Howard's article, and extending the technique to the study of multidimensionality of taste impressions. Interested readers are invited to contact the Librarian, MRL, to have their names placed on the mailing list.

Part I of this paper pointed out that data from taste panel studies tend to lack reproducibility, reliability, and validity. Some ways of remedying the lack of reproducibility and reliability were discussed, and it was suggested that the method of direct ratio estimation offered a possible technique for producing valid scoring of the magnitudes of subjective properties. Part II discusses an application of this technique which permits lack of validity to be detected. The paper is illustrated from results for various properties that might be expected, *a priori*, to give scores of varying validity.

Validation by Complete Paired Comparisons

Validation of ratio scales obtained by direct ratio estimation can be obtained by an extension of a technique first used by Comrey (1950). He suggested that if ratio estimates were made of the magnitudes of a property for all the $N \times (N-1)/2$ pairs of a set of N samples, scores on a ratio scale could be obtained for each sample, subject only to any arbitrary setting of the scale unit. Comrey used the reported ratios for his calculations, but Torgerson (1958) showed that the logarithms of the ratios should be used, and that the logarithms of the scores so estimated were least squares estimates. When the scores have been estimated their ratios can be computed and compared to the original data as a basis of validation. However, Torgerson stated that no rigorous statistical test of goodness of fit had yet been devised.

Analysis of Variance Approach

The basis of the technique suggested by Torgerson is indicated in Figure 1. The logarithms of the observed ratios R_{ij}

$$\left[R_{ij} = \frac{S_i}{S_j} = \frac{\text{Score for magnitude of sample } i}{\text{Score for magnitude of sample } j}\right]$$

are entered in their appropriate cells in the upper right triangle of the diagram, their negative values (i.e. the logarithms of R_{ji}) in the lower left triangle, and zeros (i.e. the logarithms of $R_{ii} = 1$) in the diagonal. It will be seen from Figure 1 that if $\sum_{k=1}^{n} \log S_k$, where S_k is the estimated score for sample k, is arbitrarily equated to zero, thus fixing the scale unit as the geometric mean of the scores, the logarithm of each score is given as the mean of the entries in each row of the diagram. The estimated scores are thus the geometric means of the ratio in each row. Clearly these estimates of the logarithms of the scores are those that would be obtained by making an analysis of variance for rows and columns of the entries in the diagram of Figure 1. It can be shown that the variance associated with the rows and also with the columns is the same as the reduction in variance of the logarithms of the original $N \times (N-1)/2$ ratios arising from fitting the N estimated log scores, and that the row and column interaction in the analysis of variance is twice the residual variance of the original log ratios after fitting the log scores. Appropriate degrees of freedom can be assigned on the basis of an analysis with the diagonal as missing plots.

For completely valid data, that is, data agreeing with the model

$$R_{ij} = R_{ik} \times R_{kj}$$

or

$$\log R_{ij} = (\log S_i - \log S_k) + (\log S_k - \log S_j) = \log S_i - \log S_j,$$

the interaction in the analysis should be zero. Hence if the experiment is replicated, or repeated under varying conditions that have been chosen to limit, or test for, expected errors, the statistical significance of the interaction, and hence of inconsistency, can be tested by higher-order interactions, provided the data conform to the requirements for analysis of variance. Also, intermediate interactions can be tested by higher-order interactions, thus giving a test of the significance of the effect of the different conditions on the scale values and on the inconsistency.

When using methods for analysis of non-orthogonal data the need to use the complete set of pairs is eliminated. A typical analysis is illustrated in Table 1 for the experiment discussed below in which six lengths were scaled using two trials each, with a panel of 10 members making duplicate estimations of the ratios of the lengths for all 15 pairs. Panel means were used in the analysis.

If, instead of estimating ratios of the magnitudes of the complete set of pairs, differences between the members of the pairs were estimated, the above technique applied to the matrix of differences (not the logarithms of the differences) would yield estimates of the scores on an interval scale and the validity of the scaling could be tested.

	1	i	j	n	
1	$\log R_{11} = \log S_1 - \log S_1 = 0$	$\log R_{1i} = \log S_1 - \log S_i$	$\log R_{1j} = \log S_1 - \log S_j$	$\log R_{1n} = \log S_1 - \log S_n$	$\Sigma = n \log S_1 - \sum_{k=1}^{n} \log S_k$
i	$\log (1/R_{1i}) = \log S_i - \log S_1$	$\log R_{ii} = \log S_i - \log S_i = 0$	$\log R_{ij} = \log S_i - \log S_j$	$\log R_{in} = \log S_i - \log S_n$	$\Sigma = n \log S_i - \sum_{k=1}^{n} \log S_k$
j	$\log (1/R_{1j}) = \log S_j - \log S_1$	$\log (1/R_{ij}) = \log S_j - \log S_i$	$\log R_{jj} = \log S_j - \log S_j = 0$	$\log R_{jn} = \log S_j - \log S_n$	$\Sigma = n \log S_j - \sum_{k=1}^{n} \log S_k$
n	$\log (1/R_{1n}) = \log S_n - \log S_1$	$\log (1/R_{in}) = \log S_n - \log S_i$	$\log (1/R_{jn}) = \log S_n - \log S_j$	$\log R_{nn} = \log S_n - \log S_n = 0$	$\Sigma = n \log S_n - \Sigma \log S_k$

Fig. 1.—Matrix of log ratios producing log scale values.

Diagrammatic Representation

While the magnitude and statistical significance of the interaction in the analysis of variance indicate the probability of absence

Table 1

Analysis of Variance of Logarithms of Length Ratio

Source	d.f.	Mean sum of squares	F
Length = Row variance	5	0·044670	5658****
Inconsistency = $\frac{1}{2}$ (Row × column variance)	10 = $\frac{1}{2}$ (5×5 − 5)	0·00001371	3·69*
Length × trial = (Row × trial variance)	5	0·00000790	2·12
Error = $\frac{1}{2}$ (Row × column × trial variance)	10	0·00000372	

of inconsistency in the scaling, they do no more than this. In the case of completely valid data, with zero interaction, if the log scores are plotted along a central zero horizontal axis and the log ratios from each row of the matrix plotted as ordinates with the log score for the column as abscissa, then the data for each row of the matrix will be represented by a line at −45° passing through the log score on the zero ordinate axis (Fig. 2). Non-zero interaction will produce departure from this pattern and the nature of the anomalous pattern—for instance the curvature of the lines—may indicate the nature of any systematic source of inconsistency.

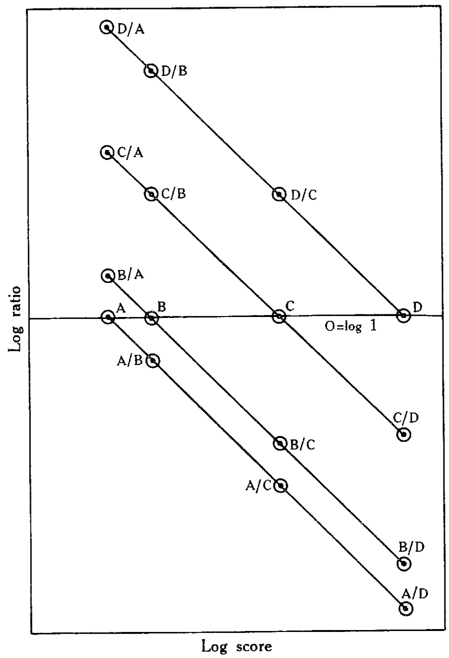

Fig. 2.—Relation of log ratios to log scales for errorless data.

Experimental Studies

As a preliminary to applying the analysis of variance approach to validating taste estimations, tests were made to see whether the panel as a whole or as individuals were capable of giving valid scaling, using direct ratio estimation, in relatively familiar situations, such as the estimation of the lengths of thin metal rods and the distance between points in a plane. If these tests were satisfactory it was logical to proceed to similar tests in less familiar conditions, such as the intensity of flavour of sapid solutions or differences in their flavour intensities.

Estimation of Length of Metal Rods

The objects for estimation of length ratios were six thin hexagonal brass rods which were placed two at a time, in pairs parallel, close together, with one end in line, and perpendicular to the line of sight of the panel member. Four replications were used with alternation between the longer and shorter rod of the pair being the nearer to the observer. The panel members were asked to state which was the longer rod and to

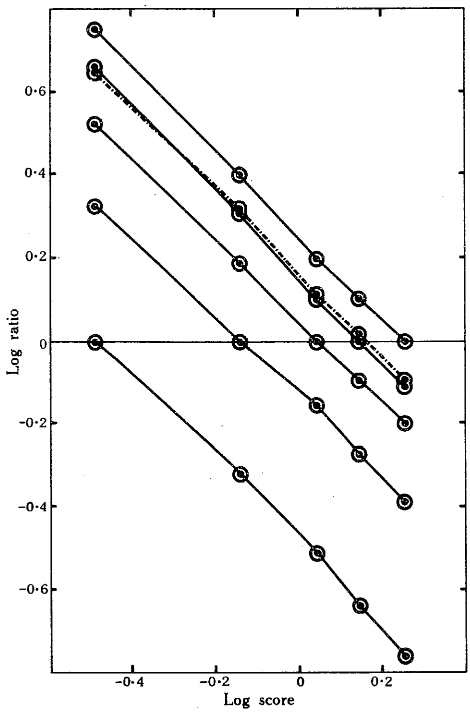

Fig. 3.—Relation of log ratios to log scores for estimated length (mean of group).

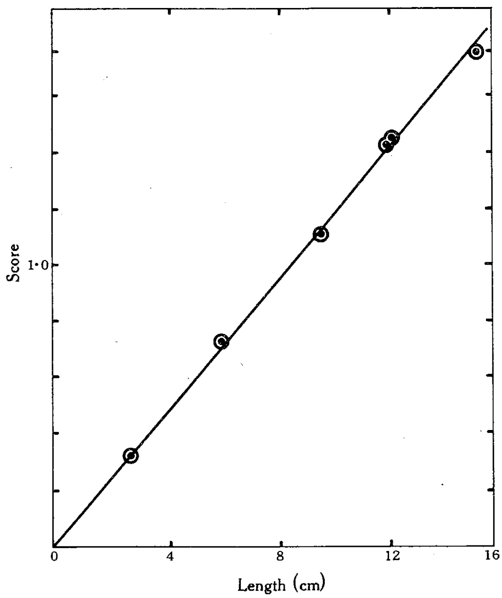

Fig. 4.—Relation between score for estimated length and actual length.

estimate, as a percentage, the ratio of the shorter to the longer.

The data showed that, with individual observers, the error variances were not homogeneous, owing to the tendency to use a restricted set of percentages. Hence statistical tests of significance could not be applied even though the estimated scores were valid least sum of squares estimates and could be diagrammatically represented. However, this objection did not apply to the panel mean log ratios. Statistically there was slight evidence of inconsistency but Figure 3 shows that it is of little practical significance and does not indicate any systematic trend. There is a close linear relationship between the logarithms of the estimated length scores and the logarithms of the physical lengths. The gradient is very close to unity and hence there is a close linear relationship between estimated length and actual length (Fig. 4).

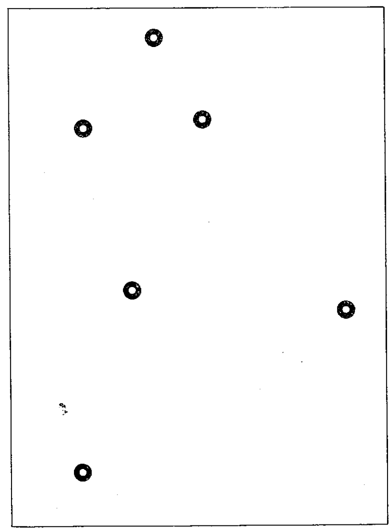

Fig. 5.—Diagram for estimation of distance in two-dimensional space.

Estimation of Distance in a Plane

The test material was a set of diagrams with six dots as in Figure 5, and observers were asked to give ratio estimations for a restricted set of 45 pairs selected from the possible 105 that can be made from the 15 lengths between dots. The set was limited to the 45 pairs that did not have a point in

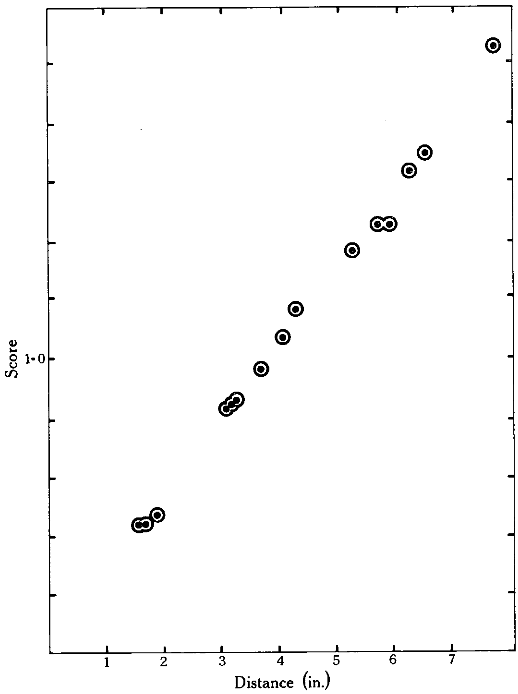

Fig. 6.—Relation between distance score and physical distance.

common, in order to minimize any variation in difficulty in estimating the ratios. The estimates were made in duplicate, reversing the order of presentation. A non-orthogonal analysis was made of the data for the panel mean logarithms of ratios. Again, there was no evidence of a consistent pattern in any inconsistency and there was a close linear relationship between estimated distance score and physical distance (Fig. 6).

Estimation of Intensity of Flavour

Tests were carried out with three sapid materials—sugar, salt, and meat extract. Four strengths of solution were used in each series and the samples were presented in pairs of beakers which, in the case of meat extract, were painted black on the outside to prevent the colour influencing the result. All six pairs of the four strengths were estimated four times, twice with the weaker solution tasted first and twice with the stronger first. The results (Fig. 7) were not as good as with estimation of length. The general convexity of the outer lines to the centre ones, particularly for sugar, suggests that when ratios become large there is a tendency to under-estimate them. This effect is statistically significant with sugar, possibly so with salt, but not significant with meat extract. From this it is evident that where the effect operates,

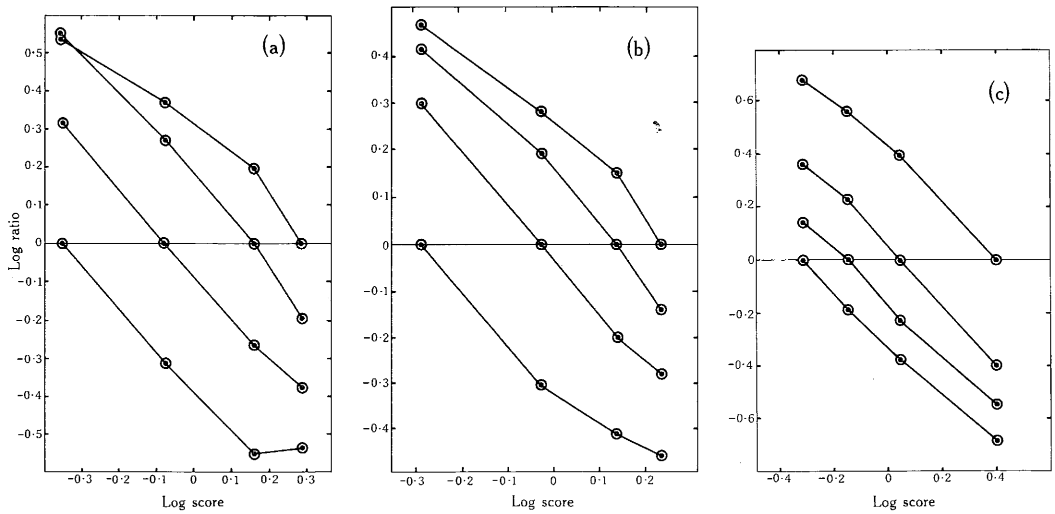

Fig. 7.—Relation between log ratios and log scores for intensity of flavour of solutions of (*a*) sugar, (*b*) salt, (*c*) meat extract.

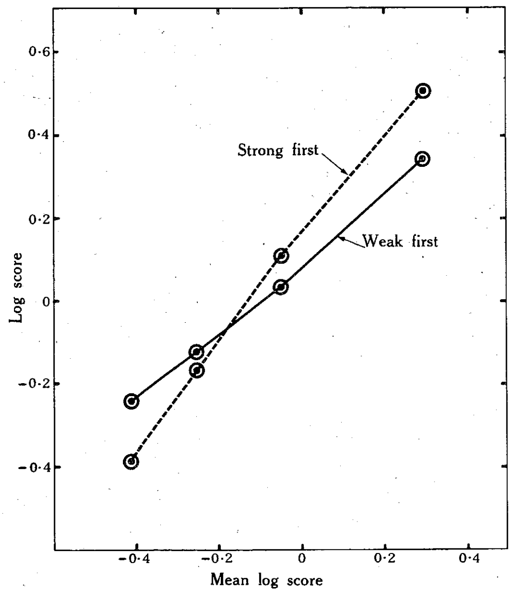

Fig. 8.—Influence of order of tasting on score for intensity of meat flavour.

large ratios must be avoided. This means that large ratios should be estimated indirectly by working with a series of intermediate samples so that all ratios actually estimated are reasonably small.

When testing with meat extract there is strong evidence that the order of presentation influences the result. In Figure 8 the scores for the two orders of presentation are shown as a function of the mean. If meaningful results are to be obtained in such a situation, both orders must be used.

In spite of the statistically significant inconsistency, the scores estimated from the mean of all the presentations fit well with the power relation:

Intensity score $= C \times (\text{concentration})^{\beta}$.

For none of the three types of solution was β greatly different from unity, and hence a reasonably linear relationship holds between estimated strength and concentration, at least for the concentrations used in these tests (Fig. 9).

Estimation of Difference in Flavour

As shown in the section on analysis of variance, if differences are estimated, scores on an interval scale can be derived from them. Meat extract solutions were examined by this technique. Ratio estimates of pairs of differences were obtained for an appropriate set of eight of the 15 pairs from the six differences obtained by examining the four solutions. Four orders of presentation were used, alternating the larger and smaller difference between pairs and alternating the stronger and weaker solutions within pairs. In this experiment there was strong evidence of inconsistency in the ratio estimation of differences, and a marked effect of order of presentation on both scores and inconsistency. However, when the six differences so estimated were used to generate the scores for the four solutions on an interval scale, there was virtually no inconsistency.

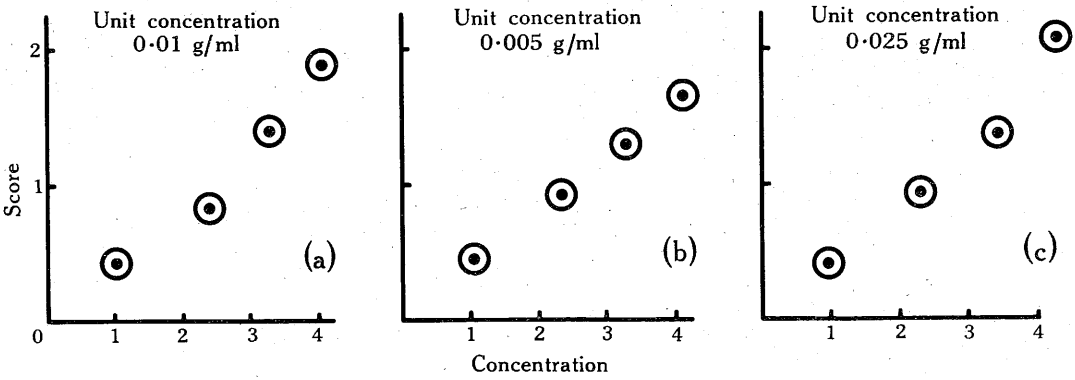

Fig. 9.—Relation between scores for estimated flavour intensity and concentration of solution.

Comparison of Interval and Ratio Scales

Though the four meat extract solutions used in the section on estimation of intensity of flavour were not all of the same concentrations as those used in the section on estimation of difference in flavour, the appropriate ratio scale scores for the latter solutions could be estimated from their concentrations, by the use of Figure 9(*c*). If both the ratio and interval scaling are valid, there should be a linear relationship between the scores on the two scales. Figure 10 shows such a relationship.

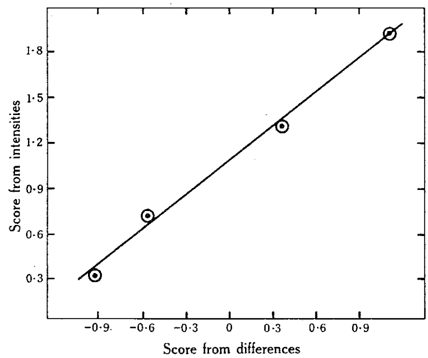

Fig. 10.—Relation between score estimated from scores for difference in flavour and the scores obtained from ratio estimation of intensity.

Conclusions

The work reported here indicates that the analysis of variance approach to paired ratios or paired differences provides a method of examining the validity of any scaling technique that produces such ratios or differences. It is also clear that, while panel members are capable of estimating ratios of length or distance with only minor inconsistency, when it comes to ratio estimation of flavour intensity of solutions, they cannot be so consistent. However, provided one alternates the order of presentation, avoids excessive ratios, and averages observers, such a technique will give scores consistent with a smooth and closely linear relationship with the concentrations of the flavoured solutions. Under such conditions, ratio estimation of flavour intensity provides a yardstick for standardizing other techniques such as subjective estimation. A similar approach is possible for the measurement of other sensory properties but when there is no meaningful zero (as, for example, in the case of tenderness), difference estimation rather than ratio estimates must be used in the final analysis, though such differences may be estimated by ratio estimation, as described in the section on estimation of difference in flavour.

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Scoring of Taste Test Data on Computer Cards

By P. G. Gipps
Division of Mathematical Statistics, CSIRO, North Ryde, N.S.W.

and D. J. Casimir
Division of Food Research, CSIRO, North Ryde, N.S.W.

Until recently, methods of obtaining and handling data from taste tests have remained essentially manual operations. This paper describes procedures by which tasters record their scores directly on computer cards enabling checking, tabulation, and analysis to be carried out by computer with a minimum of manual involvement.

In the past, when taste tests were run at the CSIRO Division of Food Research each taster was required to fill in a score form by hand as the samples were tasted in a nominated permutation. The information on these forms was transferred by hand to a master table in which the treatments were listed in a standard order. The scores from this table were then analysed by hand or punched onto cards and processed by computer.

This procedure had several disadvantages: it was slow because it involved two transfers of information by hand, and it was subject to error during both these transfers. A tasting experiment did not need to be very large before the two operations took several man-days. The transfer of information from the tasters' forms was particularly time-consuming, as the scores had to be unscrambled from the tasters' permutations to the standard order used in the master table. This operation was very slow and highly susceptible to error, and consequently had to be carefully checked.

A system in which the tasters record their scores directly onto computer cards has two advantages: it reduces to one—the act of the taster recording his score on the card—the number of operations in which an error is likely to occur; and it enables sorting and tabulating to be carried out by the computer with great savings in time.

IBM Port-a-punch System

Three main systems may be used for recording data on cards: (i) cards are marked with a pen or pencil and then read by a mark-sensing device, (ii) holes are punched in IBM Port-a-punch cards, or (iii) a keyboard card punch is located in each tasting booth. The IBM Port-a-punch system was chosen for these Laboratories because it permitted precision placement of the record on the card, and it was simpler, was compatible with the card-reading system available, and was less expensive than installing keyboards in each booth.

Masking techniques make it possible to associate instructions and sample codes with specific areas of the card in a way that is not possible with a keyboard. The Port-a-punch system has an additional advantage over keyboards in that tasters are not constrained to answer questions in a fixed sequence and are able to check their own cards for omissions and mispunchings.

Port-a-punch System in Round-robin Tests

For a tasting experiment on passionfruit juice it was decided that a round-robin or games tournament would be an appropriate form of presentation, i.e. the samples would be compared in pairs in all possible combinations, and the data would be evaluated using a Scheffé analysis.

Figure 1 shows the standard and modified Port-a-punch. The modification entailed slotting the plastic card holder on a milling machine so that 1·59-mm-diam. rods located in these slots could be used as hinges for pages carrying instructions and questions for the tasters. The pages were made of double plastic sheeting and heat sealed so that the

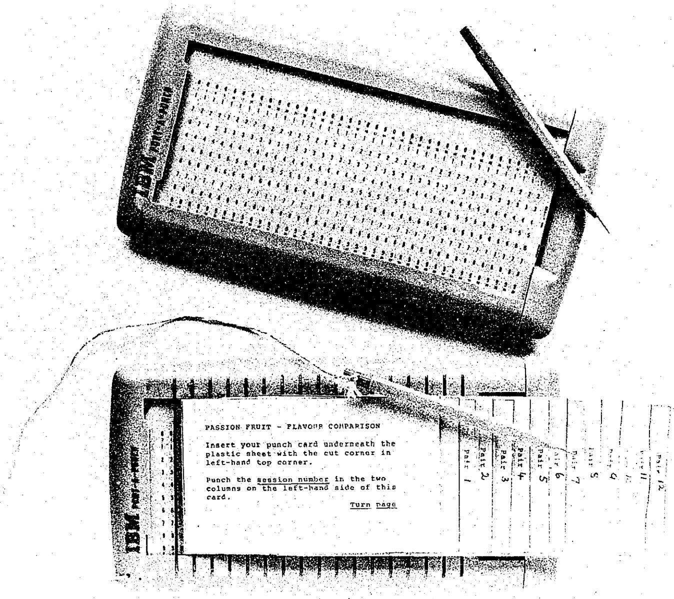

Fig. 1.—The standard IBM Port-a-punch (*top*) and (*bottom*) one modified for use with plastic pages.

instruction sheets inserted into the pockets could be changed to suit different types of taste test formats. The hinge rods were held in position with adhesive tape. The instructions to the tasters and questions to be answered are set out in Figure 2.

This experiment was designed to examine four samples in all six possible paired comparisons, and these pairs were presented so that one half of the panel tasted one sample of each pair first and the other half of the panel tasted the other sample of the pair first. This procedure was slightly different from that proposed by Scheffé (1952), and was adopted to reduce the number of sessions required.

The tasters also received the form set out in Figure 3 which gives details to be punched onto the card, i.e. the taster's identification number, the experiment number, the pairs to be tasted at the session, and the order of tasting. In this test each taster assessed three pairs at each of two sessions. The Port-a-punch card was re-issued to the taster at the second session so that all the opinions of each taster were on the one card.

Port-a-punch System with Rating Scales

Figure 4 shows a Port-a-punch modified for an apple juice tasting experiment involving a rating scale. The modification consisted of replacing the standard IBM plastic mask, which has locating holes, by a composite mask made by sandwiching between two standard masks a paper mask with instructions for tasters. The data from a single session only were recorded on each card so that the mask indicated where to punch the session number (Session 5) and the taster's identification number (Taster number 149).

The next section on the mask gives the order in which the samples were tasted. To the right of the cut-out section was a small label bearing the reference order of the samples; this label was stuck on the upper plastic mask and was changed between sessions. On the top right corner of the punch card which the taster took into the booth were the letters indicating in which order he was to taste the samples. In Figure 4 the order is R Q B and the taster indicated this on his card by punching a hole in column 1 level with R, in column 2 level with Q, and in column 3 level with B. R, Q, and B now correspond to columns 1, 2, and 3 in the section labelled General Acceptability and the taster proceeded to record his opinions by punching a hole in the appropriate column level with the comment that corresponded with his assessment of the sample.

When there is insufficient room on the paper mask to record all instructions it is

PASSION FRUIT - FLAVOUR COMPARISON

Insert your punch card underneath the plastic sheet with the cut corner in left-hand top corner.

Punch the session number in the two columns on the left-hand side of this card.

Turn page

Now punch your taster identification number in the three columns to the right of this card.

You are presented with several pairs of passion fruit products as indicated on the following pages.
Taste the pairs in the order indicated on the form accompanying the samples and indicate by punching opposite the sample having the preferred passion fruit flavour. Also indicate a no preference or a degree of difference by punching opposite the appropriate category.

TURN TO APPROPRIATE PAIR

Pair

Sample ___ has more desirable P.F. flavour 1

Sample ___ " " " P.F. flavour 2

(If you are unable to detect a flavour difference punch 0 in the right hand column i.e. difference not detectable)

The difference is:

0 Not detectable

1 Just detectable

2 Easily detectable

3 Very easily detectable

4 Very pronounced

Pair

Fig. 2.—Instructions to tasters set out on leaves attached to modified Port-a-punch.

PASSION FRUIT TASTING

Name ____________ Experiment No: ______

Taster No: ______

Please taste samples in the following order:

Pair No.	Codes

Fig. 3.—Form used for showing order of tasting.

necessary to have a separate instruction sheet in the tasting booth or to use the plastic pages described in the previous section.

In rating scale experiments the blank side of the Port-a-punch card is placed upward under the mask. This is to prevent tasters from confusing the figures on the Port-a-punch card with the scale on the paper mask. All necessary translation or decoding is readily handled by the computer.

General Comments

The Division's taste testing facilities were described by Christie (1964). Before entering the individual tasting booths, each taster takes a punch card which in a rating scale test bears the codes of the samples in the order in which they are to be tested. The taster first punches his identification number onto the card from a list of tasters' identification numbers kept in each booth.

Tasters were instructed that if they made a mistake in punching they were to continue punching the card as if no mistake had been made and after the card had been withdrawn from the holder they were to draw a circle around any hole that had been punched in error. The mispunched cards were then corrected outside the tasting booths by placing the incorrect card on top of a blank card in the Port-a-punch and repunching all holes not circled.

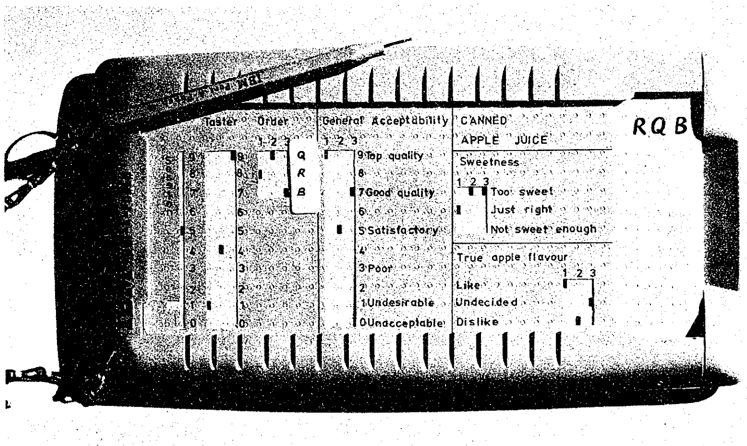

Fig. 4.—IBM Port-a-punch modified for an experiment using a rating scale.

Card Handling and Processing

Initially difficulties were experienced in reading the IBM Port-a-punch cards into the computer at high speeds (1200 cards per minute), probably because of the roughness of the cards induced by the partially punched sections, and perhaps accentuated by unavoidable damage caused by handling the cards. The partially punched sections of the Port-a-punch cards made them susceptible to mutilation in card-handling equipment; if a card became buckled or folded, the information on it was often lost as additional sections were knocked out. This problem was eliminated by first reproducing the tasters' cards on the IBM 519 card reproducer. This method was chosen in preference to adjusting the card reader, because the standard cards are less likely to be damaged than the IBM Port-a-punch cards.

Reliable checking of the cards for mispunchings or omissions overlooked by the taster was difficult to do manually, and the use of the slower reproducing punch, while preventing damage to the cards, provided another possible source of error. Checking was therefore automated using a routine that buffered the cards into the computer and checked for multiple punchings in a column, blanks in a column that should have been punched, or punched holes in a column that should have been blank. The routine also checked the order of tasting to ensure that each position had been filled, and tabulated the sessions attended by each taster.

After any errors had been detected and corrected the cards were operated on by another programme which sorted and unscrambled the data before analysing them according to the specified design. The computer used for the processing was a Control Data 3200 with 16,000 memory locations, and the programmes were designed for this machine. Further work is being carried out to produce programmes less machine-dependent than those currently in use.

Conclusion

Direct scoring of taste test data onto Port-a-punch cards leads to considerable savings in time and labour in the period between completing a tasting experiment and obtaining the analysed results. In this way results from early taste sessions may if necessary be tabulated and analysed before commencing the next sessions. As a consequence, the experimental designs used can become more flexible, since an experiment may be terminated early if sufficient information has been obtained before the experiment runs its full course. The possibility also exists of carrying out further experimentation before samples have deteriorated in quality if the results are inconclusive. Thus savings in time and labour from direct scoring can add considerable flexibility to taste testing experiments.

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Water in the Vapour Phase and its Interactions with Foods

By Wally Szulmayer

Division of Food Research, CSIRO, North Ryde, N.S.W.

This paper is based on a talk given at the Fifth Convention of the Australian Institute of Food Science and Technology in Sydney in June 1971. The talk was one of three in a symposium on laboratory techniques for the determination of water in foods.

Water vapour is the most variable constituent of the atmosphere. Its percentage by volume may range from 2×10^{-6} at high altitudes or in Antarctica to 4–5 in equatorial and subtropical regions. In middle latitudes these extremes do not occur, but the water vapour content of the atmosphere can still vary widely. As most products continuously adjust their moisture contents by sorbing and desorbing water, determination and control of these moisture exchanges are important in many industrial processes. Food technologists in particular are often concerned with controlled removal of water (dehydration and freeze drying) to reduce weight and extend storage life, and with prevention of moisture exchanges in packaging and bulk storage.

Fundamental Concepts and Definitions

Moist air is regarded as a mixture of water vapour with air; in 1947 the following definitions were internationally agreed on:

The mixing ratio (r) of moist air is the ratio of the mass of water vapour (m_v) to the mass of dry air (m_a) with which the water is associated:

$$r = \frac{m_v}{m_a}\left(\frac{\text{kg H}_2\text{O}}{\text{kg dry air}}, \frac{\text{lb H}_2\text{O}}{\text{lb dry air}}, \text{ or } \frac{\text{gr H}_2\text{O}}{\text{lb dry air}}\right)$$

Absolute humidity (d_v), the density of water vapour in a mixture, or vapour concentration, is defined as the ratio of the mass of water vapour (m_v) to the volume (V) occupied by the mixture:

$$d_v = (m_v/V)(\text{kg/m}^3 \text{ or lb/ft}^3).$$

In older air-conditioning publications and some dehydration textbooks absolute humidity is often related to unit mass instead of unit volume and stated in units lb H_2O/lb dry air.

The vapour pressure (p) of water in moist air at a total pressure (P) and mixing ratio (r) is defined as the partial pressure exerted by the water vapour:

$$p = x_v P = [r/(0\cdot620 + r)]P,$$

where $x_v = r/(0\cdot620 + r)$ is the mole fraction of water vapour in a given sample of moist air.

Saturation. Moist air at a temperature T and total pressure P is regarded as saturated when it coexists in equilibrium with a plane surface of pure water (or ice) at the same temperature and pressure. Accordingly, the definitions of mixing ratio, mole fraction, and water vapour pressure apply to the saturation state when appropriate values r_s, x_s, p_s are used.

Dew point (DP) is the temperature at which air reaches saturation when it is cooled without addition or removal of water.

Relative humidity (RH) is defined as the ratio (expressed in %) of the mole fraction of water vapour in the air (x_v) to the mole fraction of water vapour in saturated air (x_s) at the same temperature (T) and pressure (P).

$$\text{RH} = (x_v/x_s)_{\substack{T=\text{const.}\\P=\text{const.}}} 100\%.$$

By multiplying the numerator and denominator of that equation by the total pressure P, the expression yields the more familiar form of relative humidity definition:

$$\begin{aligned} RH &= (x_v P / x_s P)_{T=\text{const.}}\ 100\,\%, \\ &= (p/p_s)_{T=\text{const.}}\ 100\,\%, \end{aligned}$$

i.e. *relative humidity is equal to the ratio of the water vapour pressure of the air to the saturation vapour pressure at the same temperature, expressed as a percentage.*

Detailed derivations of all parameters related to the thermodynamic state of moist air were reviewed by Harrison (1963).

Control of Water in the Air

The essential preliminary step towards controlling the humidity of the air is the ability to predict what will happen in situations of simultaneous temperature and moisture changes. This is most conveniently done, without any mathematical effort, by means of the psychrometric chart, where some basic calculations of heat and mass transfer are presented graphically (Fig. 1). Several interrelated variables determining the thermodynamic state of the moist air are plotted on the same graph, so that when one parameter is changed the simultaneous variations of all the others can be found immediately.

The maximum amount of water that can be contained in 1 lb of air, plotted against air temperature, gives the saturation line (100% RH). Corresponding curves of constant lower values of RH are the next parameters. Also included is a family of lines representing constant enthalpy (enthalpy or total heat content is the sum of the sensible heat of the air and the latent heat of the water vapour). These lines are popularly called the wet-bulb temperatures. Finally air density, which also varies with air temperature and moisture content, is recorded as another set of slanted lines.

This composite graph is used to follow changes during basic thermodynamic processes as shown in the following examples:

(1) *Heating* of air without adding or removing moisture is represented by a horizontal line, e.g. *A–B* (Fig. 1). As evident from the graph the dew point and mixing ratio of the air remain constant at 77°F and 140 gr H_2O/lb dry air respectively, while the enthalpy, wet-bulb, and dry-bulb temperatures increase. Relative humidity is lowered drastically, a great advantage exploited in natural drying and commercial dehydration processes.

(2) *Cooling* of air is the reverse of the heating process. For example, if air at point *C* (110°F, 76% RH) (Fig. 1) is cooled, its RH increases until saturation is reached at point *D* (dew point 100°F). Cooling below the dew point proceeds along the saturation line and water vapour is removed from the air by condensation. Quantities of water condensed can be considerable as evident

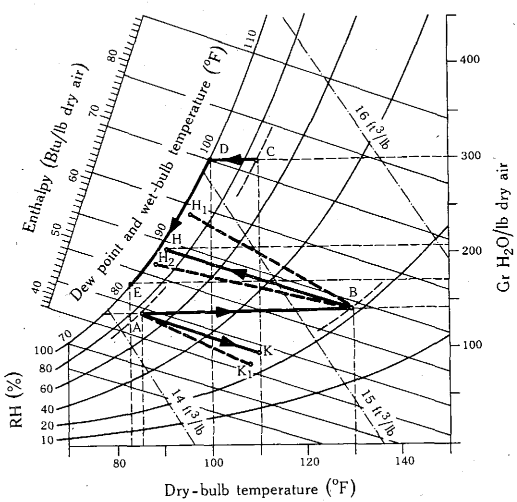

Fig. 1.—Psychrometric chart.

from this example: between *D* and *E* (dew points 100°F and 83°F respectively), 130 gr water per lb dry air will be condensed. The danger of damage from condensation is always present when cold materials meet warm air, e.g. when goods transported by ship, train, or lorry from colder districts enter warm humid regions. It is also common in storage sheds that experience large diurnal temperature fluctuations. The remedy is to ventilate with drier air, i.e. with air having a dew point below the temperature of the goods. The relative humidity of the air is an unreliable criterion of its moisture content if temperature differences are present.

(3) *Adiabatic evaporative cooling* (Fig. 1, *B–H*) occurs when air encounters a water surface or spray of the same wet-bulb tem-

perature. As the latent heat of vaporization is supplied by the sensible heat of the air, its dry-bulb temperature drops. But the evaporated water enters the air stream as vapour, so its latent heat remains in the air. Thus no net heat loss or gain occurs in the process, and the enthalpy and wet-bulb temperature remain constant. As evaporation continues dry-bulb temperature decreases, while RH, dew point, and mixing ratio all increase. The adiabatic process provides the basis for RH measurements by wet- and dry-bulb psychrometers, and is also commonly encountered during the early stages of dehydration when so-called 'constant rate' drying occurs.

(4) *Non-adiabatic evaporation* (Fig. 1, B–H_1 or B–H_2) takes place when heat is gained or lost by the moist air during the evaporation process, i.e. when the process does not follow the constant enthalpy lines. In the first case (B–H_1), additional heat is supplied by conduction or radiation, so the air gains sensible heat as well as latent heat from the product. It approaches a higher saturation temperature and can take up more water than in adiabatic evaporation. It is most commonly encountered in solar drying or dehydration with direct heating of the product. In the second case (B–H_2), sensible heat is lost to the surroundings by convection and/or conduction, e.g. the 'falling rate' stage of dehydration where the temperature of the product rises.

(5) *Chemical dehumidification* (Fig. 1, *A–K*) occurs when water is extracted from the air by sorbents such as silica gel, alumina, or phosphorus pentoxide. As the heat of sorption is released, the temperatures of the sorbent and of the air both rise. In ideal conditions, the process can be adiabatic (*A–K*). In practice, however, there is considerable deviation (A–K_1), as part of the enthalpy remains in the heated sorbent.

(6) *Mixing of two air streams* is common in air-conditioning and dehydration, when exhaust air is partly recirculated and some fresh 'make-up' air is introduced. When two air streams *A* and *C* (Fig. 2) with different temperatures and relative humidities are mixed, all possible mixture combinations can be found on the connecting line *A–C*, and the thermodynamic state of the mixture will depend on the ratio of the components, e.g. 75% exhaust air (*C*) and 25% fresh air (*A*) will result in a mixture represented by point *D*, situated a quarter of the distance from *C*. A typical recirculation process encountered during dehydration is illustrated on the graph: ambient air *A* (82°F, 43% RH) is heated to *B* (145°F, 8% RH) and passed through the dehydrator where it takes up water adiabatically (*B–C*). Seventy-five per cent of this nearly saturated exhaust air (*C*) is mixed with 25% of fresh air (*A*) and reheated to 145°F (*E*) before again passing over the drying product. During subsequent recirculation the cycles are repeated (*DEFG*, *GHIJ*, *JKLM*, etc.) until steady-state conditions (*MNOM*) are established with the wet-bulb temperature in the dehydrator remaining constant for the duration of the 'constant rate' drying period (102°F in this example).

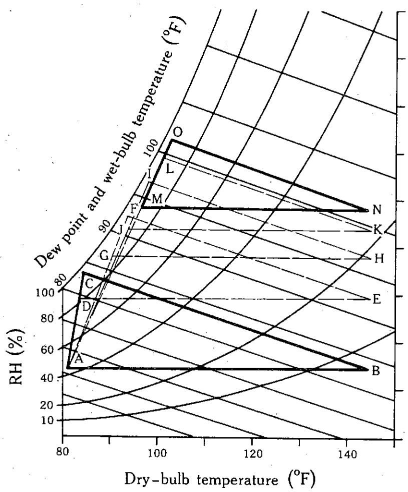

Fig. 2.—Mixing of two air streams.

Moisture Exchanges between Air and Foods

As the properties of foodstuffs and their storage life are affected by the addition or removal of water, the food technologist or the packaging expert should be able to predict the direction of moisture exchanges. For example—will the product gain water from or lose it to the surrounding air when simultaneous temperature and humidity changes occur? The hygroscopic properties of foodstuffs are best described by sorption isotherms which relate the water content of the product to its vapour pressure or equilibrium relative humidity (ERH). By definition the ERH of

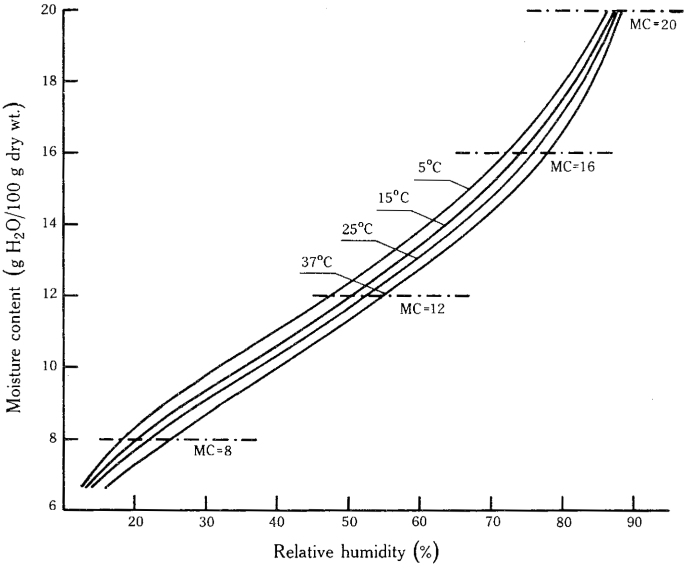

Fig. 3.—Sorption isotherms of wheat.

a product is defined as the relative humidity of the surrounding air in which it neither gains nor loses water. Knowledge of this condition allows quantitative predictions of product stability to be made. As an example, sorption isotherms of wheat at different temperatures are represented in Figure 3, as:

$$MC = f(ERH)_{T = \text{const.}}$$

where
MC = moisture content (g H_2O/100 g dry solids).
If the parameters are rearranged in the form

$$ERH = f(T)_{MC = \text{const.}}$$

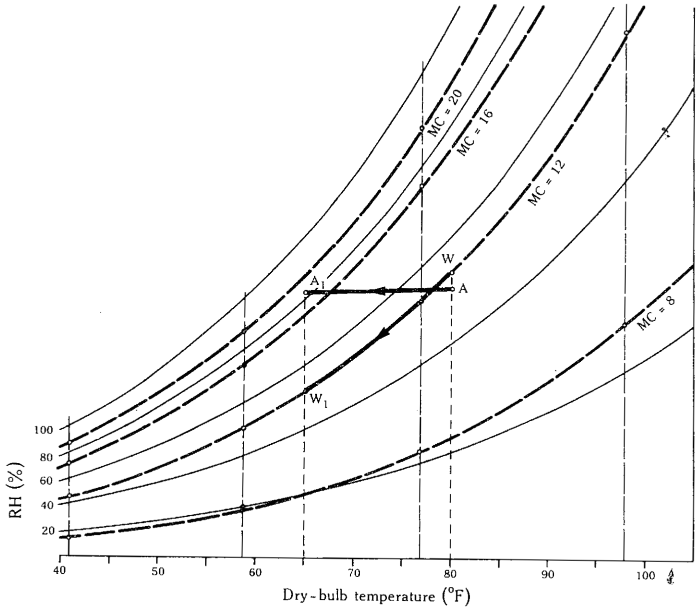

Fig. 4.—Cooling and humidification of wheat in open air.

they can be incorporated into the psychrometric chart (Fig. 4) for direct comparison with air conditions. For example, during the day when air is at point A (80°F, 50% RH), wheat at W (80°F, 12% MC) is likely to lose some water. However, at night when the temperature falls to 65°F, the state of air will be changing along the horizontal line (A–A_1) while the wheat will be cooling along the constant MC path (W–W_1). Therefore at 65°F the wheat is likely to sorb water and its moisture content will increase. In such situations, however, it is worth while to distinguish between storage conditions outdoors or in buildings with large empty spaces, and storage in closed spaces or small containers.

In the first case, which can be called the open-air system, there is an almost unlimited reservoir of water vapour in the air, which, when sorbed continuously, can damage the product. In the reverse conditions, a wet product exposed to dry air will dry out. But, because sorption is spontaneous, surface wetting will generally proceed faster than the opposite process of drying out, so that usually the net result of day–night temperature cycling over a long period is for the product to gain moisture rather than lose it.

In the second set of conditions, involving closed containers, the air volume is limited and the amount of water likely to be exchanged with the product is also limited. In the same way as saturated salt solutions, H_2SO_4–water mixtures, or silica gel provide constant humidity atmospheres in closed containers, any comparatively large volume of foodstuffs or other hygroscopic material controls the relative humidity of the surrounding air space. Usually a few hours after packing of the product, equilibrium is established and the vapour pressure of the product and air space are the same. This equilibration is the basis of a direct method of ERH measurement using selenium dioxide probes developed at the CSIRO Division of Food Research (Szulmayer 1968).

Moisture Exchanges between Foods via the Vapour Phase

It is more useful to know the vapour pressure or the ERH of a product than to know its moisture content, in order to solve many of the water transfer problems that occur in food technology. For example, in ready-mixed convenience foods such as soup or cake mixes, breakfast foods with dried fruits, and gelatine sugar mixes, products with different moisture contents and different ERH levels may be packed together. In the subsequent process of equilibration, water from one component may diffuse to another, which can be detrimental to the storage life of the product. Data in Figure 5 illustrate such a case. Two products with different sorption

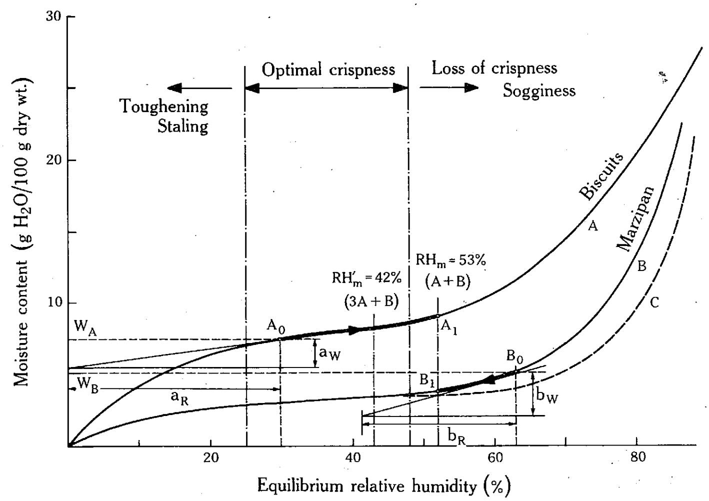

Fig. 5.—Moisture exchange between products.

isotherms are packed together; product A is initially at a moisture level W_A and product B has a moisture content W_B. As moisture transfer via the air is determined by vapour pressure gradients, product B with a higher ERH will lose water and product A will sorb it.

The apparently paradoxical situation where a 'drier' product, i.e. one containing less water, transfers moisture to a 'wetter' one has been proven experimentally by Salwin and Slawson (1959).

The equilibrium relative humidity of a mixture can be calculated approximately as:

$$R_m = \frac{R_A S_A W_A + R_B S_B W_B}{S_A W_A + S_B W_B},$$

where

R_A, R_B, R_m = equilibrium relative humidities of products A, B, and their mixture,
W_A, W_B = moisture contents of A and B resp. (% dry basis),
S_A, S_B = slopes of the isotherms A and B along their respective sorption and desorption paths,
S_A = a_W/a_R,
S_B = b_W/b_R.

It should be noted that when the slopes of the sorption isotherms change considerably within the intervals involved in moisture exchanges between two products, several approximations have to be made.

If the mixture contains more ingredients, the numerator and denominator are extended to include the additional products. Mixtures must be compounded so that the ERH critical for the deterioration of the most sensitive ingredient is not exceeded. Figure 5 shows the specific danger zones (Heiss 1968) for quality deterioration of biscuits in terms of ERH instead of moisture content. An important criterion for the acceptability of biscuits is their crispness. Fillings should not, therefore, contribute so much moisture that the ERH is raised to such a level that crispness of the biscuits is lost. Assuming that line A represents the sorption isotherm of biscuits and B the isotherm for marzipan filling, if a formulation using equal weights of A and B is employed, its equilibrium relative humidity ($RH_m = 53\%$) indicates that the biscuits will have lost their crispness. If, however, three parts by weight of A were used with one part of B the equilibrium would be shifted to $RH'_m = 42\%$, which is still within the optimal crispness range. Other ways of lowering the ERH of the biscuit creams are to modify the recipe of the filling in order to flatten its sorption isotherm in the 50–70% interval as indicated by line C, or reduce its ERH to point B_1.

For many problems of food technology, knowledge of the whole sorption isotherm is unnecessary. A few 'spot' measurements of critical ERH values often provide sufficient information to predict the life expectancy of a product or to indicate that changes in recipe, processing, or packaging are needed.

Traditionally, moisture content has been the parameter measured and quoted for the purpose of defining the chemical composition of a product, as well as its state of dryness or wetness. However, results of research over the last 10–15 years show that more scientists are recognizing the significance of ERH.

Microbiologists started the trend by establishing minimum water activity requirements for microbial growth (Scott 1953; Christian 1963). Enzymatic changes have also been related to water activity, as well as moisture content of the substrate (Acker and Lück 1958; Acker 1962, 1969), and last but not least, the substantial amount of work and discussion devoted to sorption isotherms of foodstuffs in recent years (Heiss 1968; Labuza 1968; Rockland 1969; B.F.M.I.R.A. 1968) points in the same direction.

Conclusion

As suggested previously by the author in 1966 and by many other investigators, ERH provides a better definition of the hygroscopic state of foodstuffs than does moisture content. It also has the following advantages:

- ERH provides a common single index for comparison of the degree of dehydration of different products. At present all products have their own processing goals in terms of moisture content, and comparison is impossible without reference to their sorption isotherms.

- A single measurement of ERH of a food product provides the following information: (1) to which specific spoilage dangers it is most susceptible, and how close it is to the safety limits;

(2) how compatible it is with other stored products and whether it is likely to gain or lose water in their presence;

(3) what packaging protection the food requires for anticipated storage conditions.

- Time-consuming, inconvenient, and often expensive methods of moisture determination can be replaced by easier and quicker ERH measurements without loss of accuracy.

Unfortunately, few humidity-measuring instruments suitable for ERH determinations of foodstuffs are commercially available at present. The sensing elements for such instruments should be small in size and have rapid response, good stability, high sensitivity, and reproducibility. Above all, they should operate without heating or cooling and should not add or withdraw water vapour from the test space. Since supply follows demand, it is expected that suitable instruments for measuring ERH will soon become available.

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News from the Division

New Appointments

Dr R. L. Johnson joined the Food Chemistry Section at FRL as an Experimental Officer, to work with Dr B. V. Chandler on a project designed to develop practical methods for de-bittering orange juice.

Dr Johnson was formerly a Teaching Fellow at the University of New England, where he graduated in Physical Chemistry in 1965. He was awarded the M.Sc. degree in 1968, and a Ph.D. in 1972 for studies on the pyrolysis of alkyl chloroformates in the gas phase.

Mr M. J. Eyles accepted appointment as Experimental Officer to work in the FRL team investigating various aspects of the microbial status and safety of foods. He will also study quality control methods for the food industry. Mr Eyles holds a first-class honours B.Sc. in microbiology from the University of Sydney.

Mr Dan Smith, whose appointment as Extension Officer in Melbourne for the Industry Section of MRL was mentioned in the last issue, has now moved into an office at the CSIRO Division of Animal Health at Parkville, Vic. (Private Bag No. 1, Parkville, Vic. 3052; telephone: 347 2311).

Mr D. R. Smith.

Visiting Worker

Dr Mogens Jakobsen of the Food Technology Laboratory at the Technical University of Denmark is a guest worker in FRL's Microbiology Section. During his year at North Ryde he will continue a research programme on germination of bacterial spores under conditions of controlled water activity (a_w) and study some effects of the a_w-controlling solutes on biochemical events during germination.

Award

Mr J. G. Zadow of DRL was awarded the M.Sc. degree by the University of Melbourne for his thesis, 'Some aspects of the ultra-heat treatment of milk'.

Work Overseas

Mr J. F. Kefford, Officer-in-Charge of FRL, travelled overseas during August–November 1972 in order to attend several conferences, and also to investigate new vegetable protein foods and the processing and utilization of horticultural products. As a member of the Executive of the International Union of Food Science and Technology, Mr Kefford attended an Executive Committee meeting in Budapest, which was followed by a symposium on 'Combination treatments in food preservation'. At a symposium on 'Environmental problems in the food industry', organized in London by the Institute of Food Science and Technology, Mr Kefford gave a talk on treatment of wastes from Australian canneries, and he spoke on the same subject and also on cold storage and ripening of pears at the Sixth International Congress on Canned Foods in Paris.

Dr R. M. Smillie, Leader of the Plant Physiology Unit, FRL, travelled to the USSR in October 1972 to participate in an international symposium on 'Genetic aspects of photosynthesis', held at the Tajik Academy of Sciences, Dushanbe.

Seminars and Meetings

The Sixth Australian Fruit and Vegetable Storage Research Conference was held at Cowes, Phillip Island, Victoria, from 23 to 26 October 1972, with active participation by members of FRL staff. The conference is organized by the Committee for Co-ordination of Fruit and Vegetable Storage Research, for which the Division provides the Secretariat. Nearly 50 papers and reviews were presented and a bound volume of proceedings, for limited circulation, should be available by March on application to Mr G. Fisher, Technical Secretary.

Among a number of scientific meetings attended by the Chief of the Division, Mr M. V. Tracey, in recent months was a symposium held by the Australian Institute of Agricultural Science on 'People and production: the rural scene in 1990'. Mr Tracey delivered a paper entitled 'Food processing trends and production'.

General

In November, FRL welcomed 30 delegates of the Commonwealth Scientific Committee and arranged a series of short lectures and a guided tour of selected laboratories, with talks and demonstrations. C.S.C. exists 'to ensure the fullest possible collaboration between the Government Civil Scientific Organization of the Commonwealth', and one of the means of achieving this is through the holding of biennial meetings in member countries, of which there are now 22. CSIRO was host to the 1972 C.S.C. meeting.

As a practical example of some of the work in which the Division is involved, delegates were served a lunch consisting largely of foods high in polyunsaturated fatty acids, and dairy and vegetable items which had been processed in a flame-sterilizer designed and built at FRL.

In News from the Division in the last issue, mention was made of interdivisional research into polyunsaturated ruminant products. CSIRO has now entered into a licence agreement with Dalgety Agri-Lines Pty Ltd of Sydney, which gives the company exclusive rights to manufacture, use, and sell polyunsaturated meat and milk products under CSIRO patent applications, both in Australia and overseas.

The agreement aims to commercialize the process developed by the Division of Animal Physiology and DRL, which avoids the 'soft' fats of polyunsaturated vegetable oil or oilseeds being 'hardened' by bacteria in the animal's rumen.

Selected Publications of the Division

From the Food Research Laboratory and Tasmanian Food Research Unit

Copies of most of these papers are available from the Librarian, CSIRO Division of Food Research, Food Research Laboratory, Box 52, P.O., North Ryde, N.S.W. 2113 (Telephone 888 1333).

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Wills, R. B. H., and Scott, K. J. (1972).—Methods of increasing water loss from apples to reduce low temperature breakdown. *J. hort. Sci.* **47**, 349–55.

From the Dairy Research Laboratory

Copies of most of these papers are available from the Librarian, CSIRO Division of Food Research, Dairy Research Laboratory, Box 20, P.O., Highett, Vic. 3190 (Telephone 95 0333).

Keogh, Barbara P. (1972).—A re-assessment of the starter rotation system. *Aust. J. Dairy Technol.* **27**, 86–7

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Muller, L. L. (1972).—Some recent technical advances and probable trends in processing of casein and milk proteins. Proc. XVIII int. Dairy Congr. Vol. **2**, pp. 382–92.

Sullivan, J. J., and Jago, G. R. (1972).—The structure of bitter peptides and their formation from casein. *Aust. J. Dairy Technol.* **27**, 98–104.

Urbach, Gerda, Stark, W., and Nobuhara, A. (1972).—Low resolution mass spectra of some unsaturated δ-lactones. *Agric. biol. Chem.* **36**, 1217–28.

From the Meat Research Laboratory

Copies of most of these papers are available from the Librarian, CSIRO Division of Food Research, Meat Research Laboratory, Box 12, P.O., Cannon Hill, Qld. 4170 (Telephone 95 2122).

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