

the application of the microscope to general questions of public health. Hassall's work on the Analytical Sanitary Commission was supported by Dr. Letheby and others, and resulted in the publication, in the *Lancet*, of reports on food products purchased in various parts of the country. The revelations in these reports, which gave the names of the shops concerned, were based mainly on microscopical examinations, and showed extensive adulteration. These reports were ultimately collected together and published by Hassall in 1855¹¹, and led eventually to the first Adulteration of Food and Drink Act of Parliament in 1860. The Society of Public Analysts was founded in 1874, and Hassall was elected a vice-president.

It is from such origins that the history of food microscopy begins, and the present paper traces this story, mainly as shown by the many books published on the subject.

The Attack on Food Adulteration (1850-1900)

Two of the earliest comprehensive publications on food microscopy were those of Hassall in 1850 and 1855, cited above^{9,11}. Hassall's work on the microscopical examination of drinking water was followed by other works, on the same subject, in 1875 by Macdonald¹², in 1879 by Hirt¹³, in 1888 by Rafter¹⁴, in 1898 by Mez¹⁵ and in 1899 by G. C. Whipple. The last book was rewritten and enlarged in a fourth edition by G. M. Fair and M. C. Whipple¹⁶. These works helped to build up a knowledge of the microscopic organisms associated with water supplies, and resulted in great improvements in hygiene.

Another early work was "Foods: Their Composition and Analysis" (1879); the sixth edition (1909) by Blyth and Blyth gave microscopical descriptions of many natural food products¹⁷. It is interesting to note that workers such as Husson, Belfield and Sharples employed the microscope prior to 1889, to distinguish between fats from different sources. In a publication of the United States Department of Agriculture, Wiley mentions these investigators, and Wiley and Crampton describe the microscopical detection of beef fat in lard¹⁸. In 1889, an American book by Matthews and Lott described the use of the microscope in the brewery and malthouse¹⁹. A small but well-known handbook that was first published in 1895 was "Aids to the Analysis of Food and Drugs"; the seventh edition by Nicholls (1952) and earlier editions gave a number of useful microscopical methods for detecting adulteration²⁰. In 1900, Mitchell's "Flesh Foods" was published, and this contained methods for their chemical, microscopical and bacteriological examination²¹. In the same year, a book by Galt appeared with the title "The Microscopy of the More Commonly Occurring Starches"²².

It is clear from the publications mentioned above that, in the fifty years from 1850-1900, food microscopy was greatly concerned with problems of adulteration in food and drink.

The Development of Structural Studies (1900 onwards)

About this time, the application of botanical science to food microscopy found expression in "The Microscopical Examination of Food and Drugs",

a now well-known book first published in 1903 by Professor Greenish; a third edition appeared in 1923²³. An accompanying volume was "An Anatomical Atlas of Vegetable Powders", published in 1904 by Greenish and Collin²⁴. Between them, these two works covered the microscopy of rhizomes and roots, corms and bulbs, stems, woods and barks, leaves, flowers, fruits, seeds, starches and flours, hairs and textile fibres, and adulterants of powdered food and drugs. Both volumes contained many detailed line drawings. Leach's "Food Inspection and Analysis" appeared in 1904 and also in 1909, and was revised²⁵ by Winton in 1913. This included a chapter on the microscope in food analysis, and contained 158 photomicrographs of food products. Thresh's book "The Examination of Water and Water Supplies" first appeared in 1904 and ran through many editions with various authors. The seventh edition (1958) by Taylor²⁶, and earlier editions, contained a chapter on the microscopical examination of water supplies.

For the German-reader, mention might be made of a book by Moeller and Griebel on the microscopy of food products from the plant field, which had a second edition in 1905 and a third in 1928²⁷. A. L. Winton published in 1906, with the collaboration of J. Moeller and K. B. Winton, his "Microscopy of Vegetable Foods", a monumental work, in English, of some 700 pages; the second edition of 1915 dealt with the microscopy of grain, oil seeds and cakes, legumes, nuts, fruit, vegetables, alkaloidal products, spices and condiments and commercial starches²⁸. A. L. Winton and K. B. Winton were also responsible for an English translation, in 1907, of Hanausek's "Lehrbuch der technischen Mikroskopie" (Enke, Stuttgart, 1901)²⁹, which dealt with the microscopical examination of starches, vegetable and animal fibres, stems and roots, leaves, flowers, fruits and seeds. The last notable publication in the period 1900-10 was a revision of Hassall's book on food, under the title "A Compendium of Food Microscopy" by Clayton³⁰.

The period 1910-20 saw the appearance of several books^{31,32,33,34} dealing partially or wholly with the use of the microscope in food analysis. Woodman's book entitled "Food Analysis" had its first edition in 1915 and the fourth, published in 1941, included a chapter devoted to food microscopy³¹. In 1917, Winton's "A Course in Food Analysis" appeared with a chapter concerned with the microscopical examination of vegetable foods³². In the same year Morris's "Microscopical Analysis of Cattle Foods"³³ appeared. Schneider's "Microanalysis of Powdered Vegetable Drugs"³⁴ and Scott's "The Microscope in the Mill"³⁵, which included descriptions of the pests of corn, meal and flour, were both published in 1920.

The twenties and thirties resulted in a number of important books some of which are still well known. One such work was Wallis's "Analytical Microscopy", which was concerned with food, water, spices and drugs; the first edition appeared in 1923 and the third in 1965³⁶. The eighth edition of Kenwood's "Public Health Laboratory Work (Chemistry)" was printed in 1925, and is an interesting historical item for those concerned with food hygiene³⁷. Moulton's book on "Meat through the Microscope" first appeared

in 1929, and was revised by Moulton and Lewis in 1940³⁸. In 1931, another German work, Gassner's book on the microscopic investigation of plant foods and food products, was published; a third edition appeared in 1955³⁹. The work of the Wintons culminated in the four volumes entitled "The Structure and Composition of Foods" (1932-39), spanning some 2718 pages in all⁴⁰. This encyclopaedic work was divided into sections dealing with cereals, oil seeds, forage plants, vegetables, fruits, milk and milk products, eggs, animal products, saccharine products, alkaloidal products, spices and extracts, and leaven; each product, as far as possible, is dealt with under macroscopic structure, microscopic structure and chemical composition.

The last thirty years has produced a few further books of interest. In 1946, Wallis's "Text-book of Pharmacognosy" was published, and this contained some information on the microscopical structure of food plants; the fifth edition was in 1967⁴¹. A useful volume entitled "Microscopic Analytical Methods in Food and Drug Control", was published in 1960 by the United States Department of Health, Education and Welfare⁴² and dealt with foreign bodies in food. Prandl's book (1961) on the histological analysis of sausage goods is extremely useful for the German-reading worker in the meat field⁴³. Parry's book on spices (1962) deals with their morphology, histology and chemistry⁴⁴. A photomicrographic atlas of vegetable anatomy by Stoll commenced publication in 1966; volume 1 contains photomicrographs of cereals, legumes and starchy vegetables and volume 2 spices, aromatics and fruits⁴⁵. Another atlas of microscopy, for use in the identification and authentication of some plant materials employed as medicinal agents, is that of Jackson and Snowdon⁴⁶. Finally, although not microscopical, the Oxford Book of Food Plants (1969), with 95 superb colour plates, depicts the gross morphology of 420 different varieties of food plants⁴⁷.

It is clear, from the publications described above, that a considerable amount of information is available in book form on the microscopy of natural products, but that manufactured food products are somewhat neglected.

General Reviews

Turning to reviews, there are two important series of papers of value to the food microscopist. The first series consists of ten papers by Butcher⁴⁸ on "The Microscopy of Food Products", in the journal *Food*, over the period 1933-35. The second series comprised forty-two papers by Essex and Shelton⁴⁹ on "Food Microscopy", also published in the journal *Food*, over the period 1956-59.

Apart from these, there are a number of other papers of *general* interest. Hohl (1948) has discussed possible applications of histological research to food processing⁵⁰. King and Weston (1950) have written on fluorescence microscopy as an aid to food and drug analysis⁵¹. Fluorescence microscopy of food products has also been discussed by Radley⁵². Charlett has described microscopical techniques for the food analyst⁵³, and has also dealt with sections

and section cutting⁵⁴. A comparison of methods for the microscopic examination of frozen tissues has been made by Hulle, Fennema and Powrie⁵⁵.

The only symposium on the microscopy of foods was at a joint meeting of the Food Group of the Society of Chemical Industry and the Royal Microscopical Society (1936). Three papers were presented: one by Hatch on "The Microscope in the Brewery"⁵⁶, a second by More on "The Use of the Microscope for Food Chemists"⁵⁷, and the third by Wallis on "The Search for Diagnostic Structures"⁵⁸. No further symposia on this topic have been held since 1936.

Specialised Literature

Papers on the microscopy of specific foods are widely scattered throughout many journals, and the literature contains well over a thousand specialised papers on food microscopy. Acquaintance with this literature shows that it covers both natural and manufactured food products. Some of the modern uses of food microscopy, revealed by this specialised literature, are as follows:

- (1) Fundamental study of the fine structure of raw food materials.
- (2) Identification of the nature and origin of the raw materials used in food products.
- (3) Detection and quantitative estimation of adulterants in raw materials.
- (4) Study of the influence of methods of preparation on the structure of raw materials and intermediate products.
- (5) Assessment of the suitability of raw materials for use in specified processes.
- (6) To study microscopic changes that occur in food products in such processing as ageing, blending, cooling, drying, freezing, heating, homogenisation, mixing, pasteurising etc.
- (7) To study the structure of the final products presented to the consumer, particularly as a function of composition and processing.
- (8) Quality control of the final product *i.e.* estimation of composition, detection of foreign bodies etc.
- (9) To relate the desirable properties (*i.e.* consumer preference) and defects in the final product to microscopic structure where possible, and to solve specific product problems related to structure.
- (10) Study of storage problems and deteriorative changes in the structure of food products.

Review of this detailed literature is outside the scope of the present paper.

The Influence of Electron Microscopy

The limit of resolution of the light microscope is 0.2 micrometre (μm) and structure finer than this cannot be resolved; the limit of *accurate* measurement

with the light microscope is about 5 times the resolving power or $1\text{ }\mu\text{m}$. Below this, diffraction effects render measurements somewhat inaccurate.

With the electron microscope, the resolution can be pushed to about 0.5 nanometre (nm), but in this case specimen preparation is more difficult and artifacts are easily introduced. The electron microscope, however, is beginning to make important contributions to food microscopy, and has already been applied to the study of flour and starch, milk and milk powders, water inclusions, cheese, butter and margarine, meat, fish and bacteria.

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