

Elsie Widdowson

The Remarkable Life of a Pioneering Nutrition Research Scientist, but an Unsung Dietitian

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Elsie M. Widdowson CH, CBE, FRS, PhD (1906–2000), was one of the outstanding nutrition scientists of the 20th century. It is less well appreciated that she trained in dietetics after her earlier training in chemistry. Her original work on carbohydrates in fruits led to the most comprehensive food composition tables ever produced. She and her long-time colleague, Professor Robert McCance, also tested the food rations that might be needed in the United Kingdom during World War II to ensure that the British population maintained nutritional status. Elsie's interest in human welfare led her to study the diets of children in post-war Germany. There, she showed the importance of "tender loving care" as well as nutritional adequacy for the normal growth of children. Although McCance and Widdowson's Food Tables are known worldwide, Elsie's other major contributions to dietetics deserve greater recognition than

they have received so far. This article, therefore, sets out to highlight just some of the contributions made by this remarkable woman. *Nutr Today*. 2016;51(2):86–92

HOW ELSIE WIDDOWSON BECAME INTERESTED IN DIETETICS

In the early 20th century, biochemists and physiologists investigated and characterized many of the essential micronutrients and showed associations between foods, their nutrient contents, and human health. Then they turned their attention to establishing nutrient requirements for health and disease and the identification and measurement of the amounts of individual constituents in foods using newly available chemical analytical techniques.

The profession of dietetics grew out of the demand at the time for individuals who understood nutritional requirements as well as how to plan menus that met the needs of those who were ill and those who were healthy. As the numbers of dietitians grew, so did professional associations such as the American Dietetic Association, founded in 1917; the Dietitians of Canada, in 1935; and the British Dietetic Association, founded in 1936.¹ These organizations aimed to enhance the health of the public, by advancing the science and practice of dietetics, by promoting dietetic training and education, and by encouraging communication between practitioners. Before this time, in Britain, many dietetic practitioners were nursing sisters (nurses), who ran day-to-day nursing care of the hospital wards. The Edinburgh Royal Infirmary was the first hospital there to develop a dietetic department in 1924.² Other hospitals followed, and gradually, the ranks of hospital dietitians in Britain grew. Miss R. Pybus, the Edinburgh Royal Infirmary's first head, showed that improved patient nutrition could reduce their readmissions and that dietetic services would help to do this. Her work received much favorable publicity, and shortly thereafter, she and other nursing sisters and physicians were awarded Rockefeller Travelling Fellowships to study dietetics and further their

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expertise in the United States and Canada, where dietetics had developed more rapidly than in Britain.

During the 1920s and 1930s, professional opportunities for women, other than those in nursing and teaching, were few in number in Great Britain. Educated women such as Elsie Widdowson turned their attention to developing new technical skills that had employment potential, such as those required in chemistry (Figure 1). Elsie Widdowson trained initially as a chemist. She developed the methods for separating and measuring the fructose, glucose, sucrose, starch, and hemicellulose in fruit and applied them to apples while working for her PhD in Chemistry, which she received from Imperial College, London, in 1931.³ She measured the changes in the individual carbohydrates in the fruit from the time it appeared on the tree until it ripened. However, Elsie Widdowson was not interested in pursuing a lifelong career devoted solely to plants; the biochemistry of humans and other animals held more appeal. Therefore, after her PhD, she worked briefly on kidney metabolism with Professor Charles Dodds at the Courtauld Institute of Biochemistry at the Middlesex Hospital in London. However, even with a doctoral degree from a superb institution and outstanding credentials, she was still unable to find a suitable long-term research position. Dr Dodds urged her to look into the rapidly developing field of dietetics for job opportunities. She did this and started working toward a postgraduate diploma in dietetics at Kings College in London under Professor VH Mottram. Here, she learned more about large-scale quantity cooking, the composition of meat and fish, and their losses during cooking.² It was in King's College Hospital in 1933 that she met Dr McCance, who was

a member of the medical staff there.³ He often visited the hospital kitchen to cook joints of meat for his study on *The Chemistry of Flesh Foods and Losses on Cooking*.⁴ Dr Widdowson was interested in his work on food composition and analysis. She had the audacity to tell him that his data on carbohydrates in fruit, which he had already published, were wrong. Her previous experience analyzing apples had led her to realize that his carbohydrate values were too low because some of the fructose had been destroyed during the acid hydrolysis.⁵ Instead of being offended, McCance obtained a grant for Widdowson to repeat all of the analyses and to correct the data. This fortuitous meeting was to lead to McCance and Widdowson's famous scientific partnership. A few years later, McCance helped Widdowson to obtain a further grant from the Medical Research Council to continue working on food composition, not only on fruits and vegetables but also nuts, and to extend the analyses from carbohydrates to protein, fat, inorganic constituents, and water.² It is a commentary on those times that even a woman with a doctorate and a dietetics diploma still needed the help of a man to obtain a grant!

During her diploma work, Elsie worked with Margery Abrahams in the diet kitchen at St. Bartholomew's Hospital.² This 6-week experience convinced her that comprehensive British food composition tables were sorely needed. At that time, none existed, and so British scientists used American tables even though the foods were often very different, only raw foods were listed, and the composition of carbohydrates was calculated by difference (eg, what was left after deducting protein, water, fat, and ash from the weight of the raw food).⁶ Elsie Widdowson rightly regarded those food tables as woefully incomplete. She did further research on the composition of fruits, vegetables, and nuts, which included water, nitrogen, fat, carbohydrate, and inorganic constituents.² In the meantime, she continued her study of dietetics and stayed in touch with Ms Abrahams, who, in 1936, encouraged her to apply for a grant to travel to the United States to learn more about dietetics. During her trip to the United States, Elsie Widdowson kept a diary, which has recently become available. Her trip is described in a companion paper in this journal.⁷

ELSIE WIDDOWSON'S DIETETIC CONTRIBUTIONS

More Complete and Improved Tables of Food Composition

Food tables compiled from analytical data on nutrients and other bioactive constituents in food were first developed in Germany. The first American food table was published in 1895 under the direction of W.O. Atwater and C.D. Woods.⁸ Elsie Widdowson quickly realized the defects in existing tables, including the American tables.



FIGURE 1. Dr Widdowson sitting at her desk in the 1990s. The photograph was taken by Mr David Reed for the National Portrait Gallery. Reproduced courtesy of Mr David Reed and Dr Eva Crane.

She believed that a more comprehensive food table with more information on carbohydrates was needed and set out to complete them. She felt that “a knowledge of the chemical composition of foods is the first essential in the dietary treatment of disease or in any quantitative study of human nutrition.”² In other words, she saw them as a working tool for nutrition and dietetic research. Widdowson and McCance built their tables on the basis of their own analytical work on fruits and nuts and published a series of monographs, the first authored by McCance, *The Carbohydrate Content of Foods*,⁹ followed by *The Chemistry of Flesh Foods and their Losses on Cooking*⁴ and *The Nutritive Values of Fruits, Vegetables, and Nuts*.¹⁰ These analyses and others laid the foundation for the first edition of the composition tables, *The Chemical Composition of Foods*, published first in 1940.¹¹ Widdowson and McCance were interested in bioavailability of nutrients and intentionally presented values of iron as ionisable iron to indicate bioavailability, which is of much greater value than simply listing iron content.¹² Their interest in bioavailability was further reflected in the inclusion of phytate values, as research suggested that phytate is an inhibitor of iron and calcium absorption. A revised second edition of the *Chemical Composition of Foods* was published during World War II (WWII), to include new foods appearing during the war such as dried eggs and whole milk powder.^{6,11} The format and content changed only slightly from the first edition. The third edition, co-authored by Dr David Southgate, included vitamin and mineral values from the analytical literature as well as data from other laboratories.⁶ Its other unique features included the nutrient composition of recipes and of many cooked dishes determined by calculating the recorded weight loss on cooking, rather than by calculating and analyzing each sample of food individually.⁶ The book was user-friendly and presented analyzed values of carbohydrates directly, rather than values based on the “by difference” method.⁶ The food industry, the diet of the UK population, and nutrition research were constantly evolving, which required a fourth edition in 1978. One of the developments of the fourth edition was computerization, and this was possible with the assistance of the British Ministry of Agriculture, Fisheries, and Food. Both the American and UK food composition tables have evolved dramatically since these early editions, and the Table outlines the differences between tables then and now in both countries.^{13,14}

Ensuring the Healthfulness of British Food Rationing Schemes

McCance and Widdowson also planned an experimental study of the British rations, which could be used during WWII if imports became impossible. Because more than 60% of Britain food supply was imported, the Germans attacked shipping bound for Britain to try to starve the

country into submission.¹⁵ As the blockade tightened, sugar, tea, coffee, bananas, oranges, meats, vegetables, flour, and prepared foods soon disappeared from the market, and home production was insufficient to fill the gaps. Government authorities soon began food rationing to deal with the growing shortages. At first, only items such as tea, sugar, and coffee were rationed. As the war progressed, many more items, including butter, cheese, meat, fish, and eggs were also rationed based on the available food supply and the needs of the military.¹⁵ The rationing proposals were widely criticized as not only being intolerable but also unhealthy, because allowances of milk, meat, eggs, and other popular foods would be extremely limited.¹⁵ Widdowson and McCance were particularly concerned about the effects of food rationing on health and the ability to meet nutrient needs and started an experimental study on the physiological effects of a rationing scheme that was solely based on locally produced available food. They and others in the laboratory acted as their own experimental subjects (see Figure 2). The weekly ration allowance tested per person was 4 oz of fat, 5 oz of sugar (including sugar in jam and marmalade), 1 egg, 4 oz of cheese, 16 oz of meat and fish, 35 oz (5 glasses) of milk a week and unlimited amounts of flour and potatoes. (Editor's note: with respect to meat and 5% added sugars, the ration was close to the US Dietary Guidelines Advisory Committee's 2015 lowest recommendations!). Happily, after 3 months on the diet, the rations appeared to support health and well-being in the volunteers. So McCance, Widdowson, and 2 other male colleagues further tested their physical fitness and endurance levels on the rations by successfully climbing some of the peaks of the English Lake District (Figure 2).⁵ The scientists therefore suggested that the rations be adopted nationally if the need arose. In fact, rations during WWII in the United Kingdom were never as severe as those tested.

The Bread Studies to Test Calcium Requirements

Before WWII, much of British bread was white and made from imported wheat, which was highly refined. The chaff was used as animal feed. Once WWII began and shipping declined, grain imports plummeted. Whole grain flours in the early 1940s differed in nutrient composition with more phosphorus, iron, magnesium, B vitamins, vitamin E, and calcium than an equal weight of white flour. For these reasons, many nutritionists considered them to be more “nutritious” and more healthful than white flour. However, much of the phosphorus in whole grain bread is present as phytic acid, and it forms insoluble salts of calcium, magnesium, and iron, which cannot be hydrolyzed in the human gut and cannot be absorbed. As part of the rationing scheme, a “National Loaf” made from 85% extraction flour was introduced (note: the extraction rate of flour is the yield of flour obtained from wheat in the milling process; 100% extraction flour would be a

TABLE Food Composition Tables in the 1930s and Today: United States and United Kingdom

	1930s	Today
United States	Atwater and Woods published the earliest food composition tables in the United States in 1896. These tables had about 2600 analyses of foods, including raw and processed foods, such as chocolate, sausage, and crackers.	Today, the United States Department of Agriculture's National Nutrient Database exists as an online database that includes the "reference source" for the food composition data, estimates on the composition of foods, and provides the foundation for other databases including that used in the National Health and Nutrition Examination Survey.
	United States Department of Agriculture researchers determined the composition of beef, fresh fruits and vegetables, and some vitamins during the early 20th century.	The database is updated annually, and contains over 8000 food items and values for up to 146 nutritional components. Ancillary and provisional tables are also available for many nonnutrient bioactives.
	Carbohydrate content was calculated "by difference" after subtracting the water, protein, fat, and ash from the food. Later food composition tables included separate analyses for crude fiber values.	
United Kingdom	<ol style="list-style-type: none"> British food composition tables developed a little later than their United States counterparts. McCance studied the composition of meat and fish, including the composition of protein, fat, and minerals. Once Widdowson joined him, they extended the research to include fruits and vegetables as well. They realized that carbohydrate content was calculated 'by difference' in the US tables, but they knew that carbohydrates should be measured analytically. Cooked, as well as raw, foods were included in the first edition of the food composition tables. The publication of "The Chemical Composition of Foods" (MRC Special Report Series no. 235), published in 1940, was not only a landmark publication, but also the beginning of a new era of scientific investigation of human diets and nutrient intakes. 	McCance and Widdowson's <i>The Composition of Foods, Seventh Summary Edition</i> , was published in 2014. It provides authoritative and comprehensive nutrient data for over 1200 of the most commonly consumed foods in the United Kingdom. In addition to new and previously unpublished data, it includes updated information on key foods such as milk, cheese, bread, breakfast cereals, and meat and meat products. There are also new entries for many foods that have become popular in recent years, such as fresh pasta and creme fraiche. Values for a wide range of nutrients (eg, proximates, vitamins, inorganics, nonstarch polysaccharides, and fatty acid totals) are provided. Additional tables cover phytosterols, carotenoid fractions, vitamin E fractions and, for the first time, vitamin K ₁ (phyloquinone), and the Association of Analytical Communities fiber.
	Carbohydrate content was initially calculated by "difference," but soon carbohydrates were measured analytically.	The tables are freely available as McCance and Widdowson's <i>The Composition of Foods Integrated Dataset 2015 (CoFID)</i> .
	McCance studied the composition of meat and fish, including the composition of protein, fat, and minerals. Once Widdowson joined him, they extended the research to include fruits and vegetables as well.	
	Cooked, as well as raw, foods were included in the first edition of the food composition tables.	
	Subsequent editions included foods analyzed by the authors and other values from the scientific literature.	

wholemeal flour containing all of the grain); whiter flours have progressively more of the bran and germ (and thus B vitamins and iron) removed and so have lower extraction rates. McCance and Widdowson suspected that the wholemeal flour, which contained inhibitors of calcium absorption, could be a problem at the very time when there were restrictions on the supply of

dairy products, which provided most of calcium in the diet.¹⁶ They tested their theory with a calcium balance study coupled with a complete analysis of all nutrients in duplicate portions of the foods that were eaten by 10 subjects, including themselves (see Figure 3).¹⁶ (Note: today, a human investigation review committee would not allow such self-experimentation!) The diets tested were



FIGURE 2. Professor McCance, Dr Widdowson, and Andrew Huxley in the Lake District during the Experimental Study of Rationing in January 1940.²

restricted in dairy products to levels proposed for rationing. The 3 breads tested were those made from 92% wholemeal flour, those made from 85% extraction flour, and those made from white flour at 69% extraction rate.¹⁶ Each experimental period lasted 3 to 4 weeks, and the whole study lasted 9 months, with crossovers for each experimental condition. In each study, 40% to 50% of calories came from the different flours. The effects of fortifying each type of flour with calcium carbonate, sodium phytate, or calciferol (vitamin D) were studied to test the hypothesis that phytate in the 92% extraction flour had deleterious effects on the absorption of calcium and interfered with calcium balance (which it did) and to see whether vitamin D could improve the situation (which it did not).¹⁶ As a result of these studies, McCance and Widdowson recommended that the 69% extraction white flour should be fortified with 65 mg of calcium for every 100 g. Likewise, the 85% wheat meal flour used in the “National Loaf” should have 120 mg of calcium/100 g and the 92% wholemeal flour should have 200 mg of calcium/100 g¹⁶ (see Figures 4 and 5). These recommendations for fortifying flour with calcium initially met with opposition because some people believed that adding a chemical such as calcium would cause kidney stones and hardening of the arteries. Eventually, the commotion died down, and calcium fortification was put into place, with one exception. Ironically, wholemeal bread, which needed it the most, was never fortified. Today, white bread is more commonly eaten than brown bread in the United Kingdom, but the bread is still fortified with calcium carbonate, even though supplies of milk and cheese are now unlimited.³

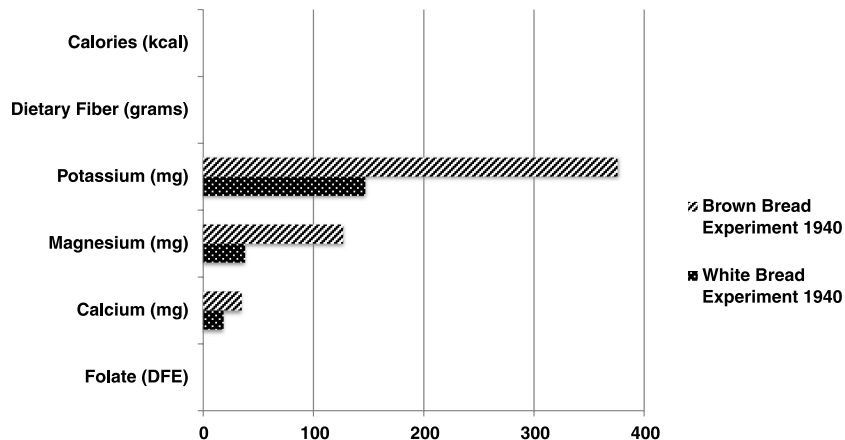
The German Orphanage Studies: Brown Versus White Bread for Growth and the Importance of “Tender Loving Care”

At the end of WWII, the population of Germany faced extreme deprivation, especially in publicly funded institutions such as orphanages. Allied occupation forces took responsibility for guarding the health of the children who were residents, but there were concerns about what to feed them. The British Medical Research Council suggested McCance and Widdowson’s visit to Germany in 1946 to examine the effects of food rationing and war among civilians, particularly among malnourished children.² They found an orphanage where they fed children different types of bread to determine whether they could subsist, thrive, and grow on a diet consisting largely of the National Loaf.³ The children were of both sexes, 5 to 14 years old, and below weight and height for age due to previous privation. Their 5 study diets consisted of either 100% wholemeal flour, 85% extraction flour (National loaf), or 72% extraction flour (white), and white flour enriched with 2 levels of B vitamins, iron, and calcium carbonate, based on the results of the studies in the United Kingdom described above.¹⁶ The study lasted 18 months. All the children improved physically and gained weight whichever bread they were eating (the extra energy supplied to the children was the most important factor in this context). The children were indistinguishable to observers, even to experts at a British Medical Association conference in the United Kingdom in 1948.

In a separate study, Elsie noted that children grew better in an orphanage that had kind caregivers, in comparison with the children given extra food in an orphanage whose caregivers who were strict and severe, especially at meal times. Her observation was one of first examples of the interaction between nutrition and psychological factors on



FIGURE 3. Dr Widdowson (center) and Professor McCance (on Dr Widdowson’s right) with members of their staff in Cambridge enjoying a meal as part of the “Bread Experiment” study in 1940. The results of this study led to the mandatory fortification of bread with calcium.³



*Information is not available for calories, dietary fiber, and folate for white and brown bread used in the “Bread Experiment” in 1940

FIGURE 4. Nutrient composition of flour in 1940. Data values are per 100 grams of flour.

growth.³ As she wisely concluded, “tender loving care of children and careful handling of animals may make all the difference to the successful outcome of a carefully planned experiment.”³ It seems that tender loving care is the best diet of all!

Synergies Between Nutrients

Elsie Widdowson’s work also demonstrated that some nutrients had synergistic effects. It was suggested from previous research that amino acids might facilitate the absorption of calcium and magnesium because these minerals were much more soluble in solutions of amino acids than in pure water. Widdowson and colleagues tested this synergy hypothesis in human studies by varying the amount of dietary protein on calcium and magnesium absorption and excretion.¹⁷ Participants were given a low-protein or high-protein diet and a moderately low-calcium diet with fixed rations of milk, 92% wheatmeal bread, sugar, and fat in both experiments with a crossover design. When protein

consumption was high, calcium and magnesium absorption increased. Widdowson concluded that while adequate protein intake may benefit calcium and magnesium absorption, a high-protein diet can never replace adequate calcium and should not be considered as a substitute for adequate amounts of them.¹⁷

Mineral Balance Study

Widdowson and McCance were always interested in mineral balance. Mrs Harris, Dr McCance’s patient at King’s College Hospital, had polycythaemia rubra vera with an elevated hemoglobin level. She was treated with acetyl phenylhydrazine, which induced rapid destruction of excess red blood cells. Widdowson and McCance collected urine and feces and noticed that there was no increase at all in the excretion of iron. Until then, it was thought that iron and zinc were regulated by active excretion and so they were determined to solve this enigma. They measured the excretion of iron in 6 healthy adults

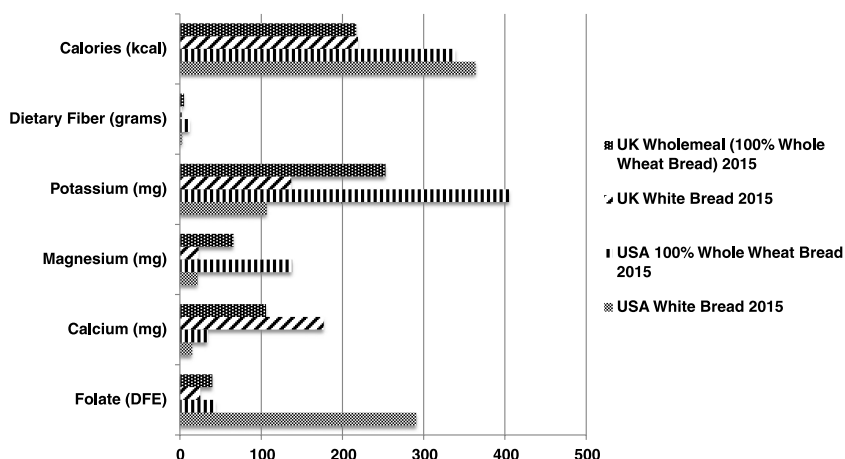


FIGURE 5. Nutrient composition of flour in 2015. Data values are per 100 grams of flour.

(including themselves) who were given intravenous ferric ammonium citrate¹⁸ (again, note that self-experimentation is forbidden today!). They were amazed to find that none of the injected iron was excreted. In a similar study, Widdowson and McCance studied zinc balance at different levels of intake as well the fate of injected zinc salts.¹⁹ They noticed that when subjects increased their dietary iron and zinc intake, urinary iron and zinc excretion was low and fecal excretion responded according to intake.¹⁸ They reached the important conclusion that the kidney does not vary its excretion of these minerals in accordance with the amount in the plasma or absorbed from the diet, confirming that iron and zinc are not regulated by excretion but are controlled by intestinal absorption.

CONCLUSION

In retrospect, it is fortunate for the profession of dietetics that Elsie Widdowson was forced, by dint of the lack of opportunities and salaried positions for women scientists, to train in dietetics. Instead of becoming bitter about the lack of employment opportunities, she brought her keen and enquiring mind and her analytical expertise as a chemist to a new field. She began with studies that led to the creation of more complete tables of food composition and went on to studies on the growth of experimental animals and humans. She and Professor McCance instigated critical experiments to ensure that, through rationing in WWII, deficiency disease was prevented and health and quality of life of British citizens were preserved. After the war, they ensured that the rations fed to German children in orphanages were sufficient to prevent the malnutrition and support good health. Elsie Widdowson never retired completely, which was fortunate for the world of nutrition and dietetics, because she continued to contribute original research well into her 80s. Although Dr Widdowson's dietetic roots were largely ignored in the early days, many prestigious bodies later honored her, including the Fellowship of the Royal Society, for her scientific research. In 1993, she was chosen to become one of Her Majesty the Queen's selected group of outstanding individuals known as her Companions of Honor, for achievements in science. In the 21st century, Dr Elsie Widdowson is remembered not only as a cherished human being but also as a role model for researchers and

dietitians. She was a superb scientist, colleague, and mentor to her students and friends on both sides of the Atlantic.

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