# The SCIENCE of FOOD

## Second Edition

An Introduction to Food Science, Nutrition and Microbiology

P. M. Gaman &
K. B. Sherrington

PERGAMON INTERNATIONAL LIBRARY

**PERGAMON INTERNATIONAL LIBRARY**
**of Science, Technology, Engineering and Social Studies**
*The 1000-volume original paperback library in aid of education, industrial training and the enjoyment of leisure*
Publisher: Robert Maxwell, M.C.

# The Science of Food

AN INTRODUCTION TO FOOD SCIENCE, NUTRITION AND MICROBIOLOGY

**SECOND EDITION**

| | |
|---|---|
| U.K. | Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England |
| U.S.A. | Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A. |
| CANADA | Pergamon of Canada, Suite 104, 150 Consumers Road, Willowdale, Ontario M2J 1P9, Canada |
| AUSTRALIA | Pergamon Press (Aust.) Pty. Ltd., P.O. Box 544, Potts Point, N.S.W. 2011, Australia |
| FRANCE | Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France |
| FEDERAL REPUBLIC OF GERMANY | Pergamon Press GmbH, 6242 Kronberg-Taunus, Hammerweg 6, Federal Republic of Germany |

---



First edition 1977

Second edition 1981

**British Library Cataloguing in Publication Data**

Gaman, P. M.
The science of food—2nd ed.
(Pergamon international library).
1. Food—Composition
I. Title II. Sherrington, K. B.
641.1 TX531 79-41578

ISBN 0-08-025896-4 (Hardcover)
ISBN 0-08-025895-6 (Flexicover)

*Printed and bound in Great Britain by*
*William Clowes (Beccles) Limited, Beccles and London*

**Other Titles of Interest**

BIRCH *et al.*
Food Science, 2nd Edition

BROWN
By Bread Alone

DUCKWORTH
Fruit and Vegetables

EARLE
Unit Operations in Food Processing

GARATTINI *et al.*
Single Cell Protein—Safety for Animal and Human Feeding

KENT
Technology of Cereals, 2nd Edition

LAMB & HARDEN
The Meaning of Human Nutrition

LAWRIE
Meat Science, 3rd Edition

YEATES *et al.*
Animal Science, Reproduction, Climate, Meat, Wool

# Preface to Second Edition

In the course of teaching applied science to catering students, we came to realise the need for a textbook which dealt with the various scientific aspects of food preparation at an intermediate level.

In this book we have covered three different subject areas; food science, nutrition and microbiology. Microbiology has been given more emphasis than is usual in books on food science and nutrition, since we feel that this is an area which is often overlooked.

This book is intended to fill the gap between elementary books, containing little scientific explanation, and advanced books which examine the subjects in detail but are only suitable for those students who have a comprehensive scientific training. We have assumed little prior scientific knowledge on the part of the reader. An attempt has been made to convey basic scientific facts and principles, necessary for the understanding of food science, nutrition and microbiology, which are dealt with in some depth.

This book is intended primarily for students following TEC diploma courses in Catering. It should also be of value to Home Economics students and students taking diploma courses in Food Science, Food Technology, Dietetics and Nutrition. It is thought that it will serve as an introduction for undergraduates following degree courses in these subjects. Science teachers in secondary schools may find it useful for developing courses in applied science. There may also be many other people, wishing to find out more about food and nutrition, who would find this book both informative and interesting.

The second edition contains revised and updated information and figures. Since writing the first edition we have felt the need to include a section on some of the more applied aspects of nutrition and have therefore written an additional chapter which includes information on the nutritional considerations of groups of people and meal planning.

# Acknowledgements

We wish to acknowledge the help and encouragement given to us by many friends and colleagues during the writing of this book. Particular thanks go to Mrs. Valerie Ward for her very valuable assistance with proof reading.

Much of the statistical data in the book has been obtained from H.M.S.O. publications. The figures relating to the nutrient content of foods are taken from *McCance and Widdowson's The Composition of Foods* by A. A. Paul and D. A. T. Southgate and from the *Manual of Nutrition*. Figures which relate to the number of food poisoning outbreaks in England and Wales have been extracted from *On the State of the Public Health, 1976.*

The table in Appendix I which shows the percentage contribution of different foods to the nutrient content of the average household diet is an abridged version of that published in *Household Food Consumption and Expenditure: 1977.* Appendix II, the table of recommended nutrient intakes, is a modified version of that published in *Recommended Daily Amounts of Food Energy and Nutrients for Groups of People in the U.K.* (1979). Both of these tables are reproduced with the permission of the Controller of Her Majesty's Stationery Office.

# Introduction

Most people do not relate science to food. Even though they are aware of the rapid development of technology and of the applications of science to many aspects of everyday life, they remain unaware of the importance of science in the preparation of the food on their tables.

Scientific study related to the food we eat can be roughly divided into three broad categories: food science, nutrition and microbiology.

Food science involves the study of all aspects of science related to food. A major part of this book deals with the chemistry of food, since this is an important aspect. An understanding of the chemical nature of food is essential if one is to achieve an understanding of the composition of food and the reactions which take place in food when conditions are changed. A study of food science will explain, for example, why baking powder makes cakes rise or why freshly cut apples go brown when exposed to the air.

Food, like oxygen, is a necessity of life. The human body requires food as a source of energy and for the growth and replacement of tissues. Food also supplies substances which help regulate the reactions involved in these processes. Nutrition is the study of the composition of food and the utilisation of food by the body. Nearly all foods are mixtures of substances known as nutrients. Each nutrient has a particular type of chemical composition and performs at least one specific function when it is digested and absorbed in the body.

The six groups of nutrients are:

| | |
|---|---|
| 1. Carbohydrates | provide energy. |
| 2. Fats | provide energy. |
| 3. Proteins | used for growth and replacement of tissue, may also be used to provide energy. |
| 4. Vitamins | regulate body processes. |
| 5. Minerals | regulate body processes; some are used for growth and replacement of tissue. |
| 6. Water | essential for body processes. |

A well-balanced diet is necessary for the maintenance of good health. This means that the food a person consumes should be planned to provide adequate amounts of the essential nutrients together with an adequate, but not excessive, energy intake. Given a selection of foods most people would choose a balanced diet, without necessarily knowing anything of the nutritional value of the different foods. However, many people in the world do not have the opportunity of such a selection and as a result, through no fault of their own, their diet is not balanced. This leads to malnutrition, which literally means 'bad nutrition'. There are many types of malnutrition. Malnutrition may be caused by a lack of one or more of the essential nutrients in the diet. For example, a prolonged lack of vitamin C will give rise to a deficiency disease known as scurvy.

Not only is malnutrition caused by consumption of foods with an incorrect nutrient balance but also by consumption of either too little or too much food. Insufficient food will lead to starvation, a form of malnutrition which, if prolonged, will lead to death. An excessive intake of food will cause obesity. In Western industrialised societies the increase in the incidence of obesity is causing concern among doctors, nutritionists and dietitians. It is unhealthy to be overweight and life expectancy is reduced. For example, for a man whose body weight is 20% above his ideal weight the risk of death is increased by 25%. Obesity is the commonest effect of malnutrition in most industrialised countries.

Microbiology is the study of microorganisms; these are very small, simple forms of life such as bacteria and yeasts. Some species of microorganisms are beneficial and are used extensively in food production. Other types are responsible for many undesirable effects in food. Certain bacteria, if present in food in large enough numbers, will cause food poisoning. Microorganisms can also cause food spoilage, e.g. the souring of milk, the growth of moulds on foods such as bread and cheese. A knowledge of the nature of microorganisms, their growth requirements and how growth can be prevented, is necessary if one is to understand correct procedures of hygiene and the principles involved in the various methods of food preservation.

In order to obtain adequate food supplies in urbanised societies, we depend very greatly on food technology. It is no longer possible for people to depend on locally grown, fresh foods. Food is now transported, often over very great distances, from rural areas where it is produced, to urban areas. Unless food is processed or preserved in some way, much of it would be unfit for human consumption by the time it reached the consumer. Food can be canned, frozen, chilled or dried in order to extend its shelf life. Preservation of food may also reduce the preparation and cooking time and is advantageous from the point of view of convenience. Many foods are 'manufactured' with convenience and acceptability in mind. Food technologists have developed a large variety of products ranging from frozen complete meals, dried soups, pie fillings and cake mixes to breakfast cereals. Food technology is becoming increasingly important in modern society.

# Contents

CHAPTER 1

# Measurement and Metrication

All scientific study involves accurate measurement. This applies to food science, nutrition and microbiology as much as to any other scientific discipline. For example, in order to assess the nutritional value of a food it is necessary to be able to state its nutrient content in precise terms.

The metric system has, for a long time, been the universal system of measurement in pure science. Being a decimal system it is logical and easy to use. Many people in Britain may still be more familiar with Imperial units (inches, pints, pounds, etc.) than with metric units (metres, litres, kilograms, etc.) but Imperial units are being phased out.

## SI units

SI is an abbreviation for Système Internationale d'Unités (International System of Units). It is an extension and refinement of the traditional metric system and it has been adopted in the United Kingdom for all scientific measurement. There are six basic SI units; each is used for measuring a different physical quantity and each is represented by a different symbol. These basic units are shown in Table 1.1.

Table 1.1. *Basic SI units*

| Physical quantity | Name of unit | Symbol |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Thermodynamic temperature | degree Kelvin | °K |
| Luminous intensity | candela | cd |

In addition there are other units, derived from these basic quantities, and also some non-SI units, still in common use, which are allowed in conjunction with SI. Units which are relevant to this book are shown in Table 1.2.

Table 1.2. *Other SI units*

| Physical quantity | Name of unit | Symbol | |
|---|---|---|---|
| Energy | joule | J | derived units |
| Customary temperature | degree Celsius | °C | derived units |
| Area | square metre | $m^2$ | derived units |
| Volume | cubic metre | $m^3$ | derived units |
| Density | kilogram per cubic metre | $kg\,m^{-3}$ | derived units |
| Volume | litre | l | allowed in conjunction with SI |

It is sometimes more convenient for practical purposes to use a unit considerably larger or smaller than the standard unit. In order to make the units larger or smaller, words can be used in front of the unit. These prefixes increase or decrease the basic units by multiples or fractions of ten. Each multiple or fraction has a symbol which is placed in front of the symbol of the unit (Table 1.3).

The following examples illustrate the use of prefixes:

5 kJ = five kilojoules = five thousand joules.
12 mm = twelve millimetres = twelve thousandths of a metre.
8 $\mu$g = eight micrograms = eight millionths of a gram.

N.B. Symbols never take a plural form; 12 mms would be incorrect.

Table 1.3.

| Multiple | Prefix | Symbol |
|---|---|---|
| 10 (ten) | deca- | da |
| $10^2$ (hundred) | hecto- | h |
| $10^3$ (thousand) | kilo- | k |
| $10^6$ (million) | mega- | M |

| Fraction | Prefix | Symbol |
|---|---|---|
| $10^{-1}$ (tenth) | deci- | d |
| $10^{-2}$ (hundredth) | centi- | c |
| $10^{-3}$ (thousandth) | milli- | m |
| $10^{-6}$ (millionth) | micro- | $\mu$ |
| $10^{-9}$ (thousand millionth) | nano- | n |

LENGTH

The basic unit for the measurement of length is the metre and this has replaced the yard. Large distances are now measured in kilometres rather than miles, and small distances in centimetres or millimetres. Very short lengths, such as the wavelength of light and the size of microorganisms, are measured in micrometres or nanometres.

1 kilometre (km) $= 10^3$ m,
1 centimetre (cm) $= 10^{-2}$ m,
1 millimetre (mm) $= 10^{-3}$ m,
1 micrometre ($\mu$m) $= 10^{-6}$ m,
1 nanometre (nm) $= 10^{-9}$ m.

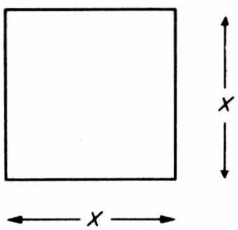
Some of the factors used for converting Imperial units to SI units are as follows:

1 inch = 2.54 cm (approximately $2\frac{1}{2}$),
1 yard = 0.91 m (approximately 1),
1 mile = 1.61 km (approximately $\frac{8}{5}$).

## AREA

Area is a physical quantity derived from the measurement of length.

$$\text{Area} = \text{length} \times \text{breadth}$$




The area of a square of side $x$ is $x^2$

The SI unit of area is the square metre.

1 square metre (m$^2$) $= 100 \text{ cm} \times 100 \text{ cm}$
$= 10^4$ square centimetres (cm$^2$).

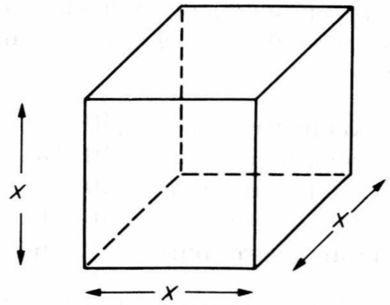
A factor used for converting Imperial units to SI units is

$$1 \text{ square yard} = 0.836 \text{ m}^2.$$

## VOLUME AND CAPACITY

Volume is also derived from the measurement of length.

$$\text{Volume} = \text{length} \times \text{breadth} \times \text{height}.$$




The volume of a cube of side $x$ is $x^3$

The SI unit of volume is the cubic metre.

$$1 \text{ cubic metre } (m^3) = 100\text{ cm} \times 100\text{ cm} \times 100\text{ cm} = 10^6 \text{ cubic centimetres } (cm^3).$$

For liquid measure or capacity the litre is the unit most often used. The litre is derived from the measurement of volume, since it was originally defined as the volume occupied by 1 kg of water at its temperature of maximum density and under a pressure of one standard atmosphere.

$$1 \text{ litre } (l) = 1000\text{ cm}^3,$$
$$1 \text{ millilitre } (ml) = 10^{-3}\text{ l}.$$

It will therefore follow that

$$1 \text{ millilitre } (ml) = 1 \text{ cubic centimetre } (cm^3).$$

Some of the factors used for converting Imperial units to SI units are as follows:

$$1 \text{ cubic foot } (ft^3) = 0.028\text{ m}^3,$$
$$1 \text{ fluid ounce} = 28.4\text{ ml},$$
$$1 \text{ pint} = 568\text{ ml } (0.568\text{ l}),$$
$$1 \text{ gallon} = 4.55\text{ l}.$$

For some purposes it is convenient to know that

$$1 \text{ litre} = 1.76 \text{ pints (approximately } 1\tfrac{3}{4}).$$

MASS AND WEIGHT

For practical purposes mass and weight are the same and the terms are interchangeable, although the scientific definitions of mass and weight are different.

The basic SI unit of mass is the kilogram, which is now used instead of the pound. It has been suggested that a new name be found for the kilogram, since it is the only basic unit which is a multiple and has a prefix in its name. Quantities formerly measured in ounces are now measured in grams. Very small quantities of substances found in foods, such as vitamins and mineral elements, are measured in milligrams or micrograms. For large weights the metric tonne is used.

$$
\begin{aligned}
1 \text{ tonne (t)} &= 10^6 \text{ g},\\
1 \text{ kilogram (kg)} &= 10^3 \text{ g},\\
1 \text{ milligram (mg)} &= 10^{-3} \text{ g},\\
1 \text{ microgram } (\mu\text{g}) &= 10^{-6} \text{ g}.
\end{aligned}
$$

Some of the factors used for converting Imperial units to SI units are as follows:

$$
\begin{aligned}
1 \text{ ounce} &= 28.4 \text{ g (approximately 30)},\\
1 \text{ pound} &= 454 \text{ g (0.454 kg—approximately } \tfrac{1}{2}),\\
1 \text{ stone} &= 6.35 \text{ kg}\\
1 \text{ ton} &= 1.016 \text{ t (metric tonnes)}.
\end{aligned}
$$

For some purposes it is useful to remember that

$$1 \text{ kg} = 2.20 \text{ pounds}.$$

## DENSITY

Density is derived from volume and weight. The density of a substance is a measure of its 'heaviness'. The popular expressions 'as heavy as lead' and 'as light as a feather' imply correctly that lead has a high density and feathers a very low density. A given weight of feathers will ocupy a much greater volume than the same weight of lead.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

Since the SI unit of weight is the kilogram and the unit of volume is the cubic metre, the SI unit of density is the kilogram per cubic metre ($kg/m^3$ or more correctly $kg\,m^{-3}$). Density is also measured in grams per cubic centimetre ($g\,cm^{-3}$). The density of water is $1.0\,g\,cm^{-3}$. The **Relative Density (RD)** of a substance is the number of times a substance is heavier than an equal volume of water, i.e. its density relative to water.

$$\text{Relative Density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

N.B. Relative density is a ratio and therefore has no units.

If a substance is dissolved in water to form a solution, the density is altered. The density varies directly with the concentration of the solution. Most substances, e.g. sugar and salt, cause the density to increase but sometimes the density may be lowered, e.g. by the presence of fat or alcohol.

A quick method of determining the concentration of pure solutions in water is to measure the density of the solution, using an instrument known as a *hydrometer*.

A hydrometer consists of a glass bulb weighted with lead shot; attached to this is a thin glass stem bearing a scale (see Figure 1.1).

The hydrometer is placed in the solution so that it floats freely. The further it sinks into the solution the lower the density. The scale may give the density of the solution or it may be calibrated to give a direct reading of the concentration of a substance. Some examples of hydrometers used to give direct readings

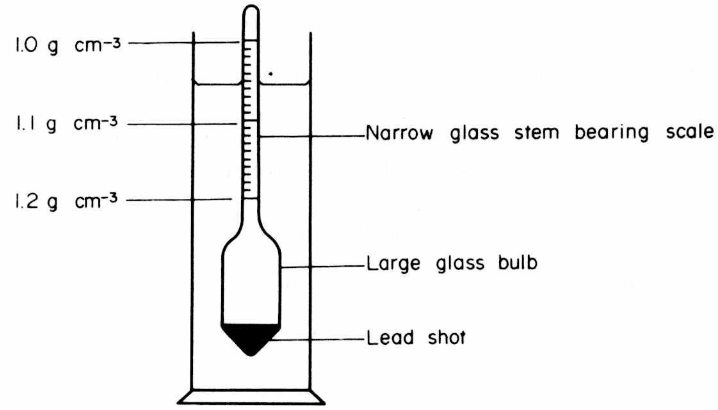



Figure1.1. Diagram of a hydrometer used to measure densities in the range $1.0\,g\,cm^{-3}$ to $1.2\,g\,cm^{-3}$.

of concentration are saccharometers, used to measure sugar in solution, and salinometers which measure the concentration of brine (salt solutions). Lactometers are used in dairies to give a rapid measurement of the density of milk, giving an indication of its quality. In the wine industry hydrometers are used to show how much alcohol has been produced during fermentation.

ENERGY

The measurement of the energy released when a nutrient or food is oxidised is of importance in nutrition. The energy value of a food can be assessed by burning the food in oxygen and measuring the amount of heat energy produced.

The SI unit of energy is the joule and this has replaced the calorie. In nutrition the kilojoule has replaced the kilocalorie.

$$1 \text{ kilojoule (kJ)} = 1000 \text{ joules.}$$

The factor used for conversion is

$$1 \text{ kilocalorie (kcal)} = 4.19 \text{ kilojoules (kJ).}$$

Kilocalories are often written as Calories (using a capital letter).

$$1 \text{ kilocalorie} = 1 \text{ Calorie (Cal)} = 1000 \text{ calories (cal).}$$

The use of the same word for two units of widely differing magnitudes causes a lot of confusion and the term kilocalorie is preferred.

TEMPERATURE

The customary unit of temperature is the degree Celsius (°C). The Celsius (or Centigrade) scale is a temperature scale in which the melting point of ice is 0° and the boiling point of water is 100°. On the Fahrenheit scale the melting point of ice is 32° and the boiling point of water is 212°.

| Fixed point | Celsius scale | Fahrenheit scale |
|---|---|---|
| Melting point of ice | 0° | 32° |
| Boiling point of water | 100° | 212° |

On the Celsius scale it can be seen that there are 100 degrees between the two fixed points whereas on the Fahrenheit scale there are 180 degrees. The ratio 100 : 180 is equal to 5 : 9 and therefore 5 Celsius degrees are equal to 9 Fahrenheit degrees.

*To convert °C to °F*
(a) Multiple by 9 then
(b) Divide by 5 then
(c) Add 32

*Example: to convert 10 °C to °F*
(a) $10 \times 9 = 90$
(b) $90 \div 5 = 18$
(c) $18 + 32 = 50$
10 °Celsius = 50 °Fahrenheit

*To convert °F to °C*
(a) Subtract 32 then
(b) Multiply by 5 then
(c) Divide by 9

*Example: to convert 104 °F to °C*
(a) $104 - 32 = 72$
(b) $72 \times 5 = 360$
(c) $360 \div 9 = 40$
104 °Fahrenheit = 40 °Celsius

CHAPTER 2

# Basic Chemistry

All foods are either pure chemical compounds or mixtures of chemical compounds. Therefore, in order to understand something of the nature of food substances and the way in which they behave, it is necessary to have a fundamental knowledge of chemistry. Substances, also termed matter, can exist in three states: solid, liquid and gaseous. Chemistry is the study of the composition and behaviour of matter.

## Atoms and elements

All substances that exist, either living or non-living, are made up of atoms. Atoms themselves are made up of smaller particles, the three main ones being the proton, the neutron and the electron. The nucleus of an atom consists of protons and neutrons. The proton has a positive electrical charge and the neutron has no charge. The electron orbits the nucleus and has a negative electrical charge, which is equal but opposite to the charge on the proton.

The simplest type of atom is the hydrogen atom. Its nucleus consists of a single proton and it has one electron orbiting the nucleus (see Figure 2.1). The carbon atom, on the other hand, has six protons and six neutrons in the nucleus and six electrons orbiting the nucleus. There are two electrons in the first orbit and four in the second orbit. Simple representations of a hydrogen atom and a carbon atom are shown in Figure 2.1.

It will be noticed that, in each case, the number of protons is equal to the number of electrons. Since the charges on the proton and electron are equal but opposite, the atom is electrically neutral.

So far, 105 different types of atoms have been discovered. This means that matter is made up of 105 fundamental substances called elements. Each element has its own type of atom; the hydrogen atom, for example, is different from the carbon atom.

**An element is a simple substance consisting of atoms of only one type. It cannot be broken down into anything simpler by any known chemical process.** By including the phrase 'by any known chemical process' in this definition, allowance is made for the fact that, since the discovery of radioactivity, certain elements, e.g. uranium, have been shown to undergo a *physical* process of decay producing other substances, i.e. other elements.