

JOSEPH NEEDHAM

# SCIENCE AND CIVILISATION IN CHINA

VOLUME 6

BIOLOGY AND  
BIOLOGICAL TECHNOLOGY

PART V: FERMENTATIONS AND FOOD SCIENCE

BY

H. T. HUANG, D. PHIL

(HUANG HSING-TSUNG)

FORMERLY DEPUTY DIRECTOR, THE NEEDHAM RESEARCH INSTITUTE, CAMBRIDGE



**CAMBRIDGE**  
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE  
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS  
The Edinburgh Building, Cambridge CB2 2RU, UK <http://www.cup.cam.ac.uk>  
40 West 20th Street, New York NY 10111-4211, USA <http://www.cup.org>  
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© Cambridge University Press 2000

This book is in copyright. Subject to statutory exception  
and to the provisions of relevant collective licensing agreements,  
no reproduction of any part may take place without  
the written permission of Cambridge University Press.

First published 2000

Printed in the United Kingdom at the University Press, Cambridge

Typeset in Baskerville 11.25/13pt, in QuarkXpress™ [GR]

A catalogue record for this book is available from the British Library

ISBN 521 65270 7 hardback

## CONTENTS

List of Illustrations	page	xiii
List of Tables		xxi
List of Abbreviations		xxiii
List of Acknowledgements		xxv
Series Editor's Preface		xxvii
Author's Note		i
<b>40 FERMENTATIONS AND FOOD SCIENCE</b>		<b>14</b>
<b>(a) Introduction, p. 14</b>		
(1) Food resources in ancient China, p. 17		
i Grains, p. 17		
ii Oilseeds, p. 28		
iii Vegetables, p. 32		
iv Fruits, p. 43		
v Land animals, p. 55		
vi Aquatic animals, p. 61		
(2) Ancient Chinese culinary system, p. 66		
i Food preparation and cooking: methods and utensils, p. 67		
ii Seasonings and spices: what they are and how they are used, p. 91		
iii Eating and drinking: dining vessels, implements and furniture, p. 96		
<b>(b) Literature and sources, p. 116</b>		
(1) Ancient classical texts, p. 116		
(2) Food canons and recipes, p. 121		
i The Chhi Min Yao Shu or Essential Arts for the People's Welfare, p. 123		
ii Early mediaeval food canons, p. 124		
iii Late mediaeval food canons, p. 126		
iv Premodern food canons, p. 129		
v Works on wine technology, p. 132		
(3) Classics of Materia dietetica, p. 134		
(4) Supplementary sources, p. 140		
(5) Secondary sources, p. 146		
<b>(c) Fermentation and evolution of alcoholic drinks, p. 149</b>		
(1) Origin of wine fermentations in China, p. 150		
(2) Preparation of ferments and wines in early mediaeval China, p. 168		
(3) Wine fermentations in late mediaeval and premodern China, p. 181		

- (4) Development of red ferment and red wine, p. 192
  - (5) Evolution of distilled wines in China, p. 203
    - i Summary of earlier evidence, p. 204
    - ii Recent archaeological discoveries, p. 208
    - iii Distilled spirit in the Thang and Sung, p. 221
    - iv Development of distilled wine in China, p. 226
  - (6) Medicated wines in China, p. 232
  - (7) Wines from fruits, honey and milk, p. 239
    - i Wine from grape and other fruits, p. 240
    - ii Wine from honey, p. 246
    - iii Koumiss and other fermented milk products, p. 248
  - (8) Alcoholic fermentations, East and West, p. 257
    - i Origin of li and chiu in China, p. 259
    - ii Origin of beer in the West, p. 263
    - iii Grain fermentations, East and West, p. 272
    - iv Special features of the Chinese system, p. 278
  - (9) Production of vinegar, p. 283
- (d) Soybean processing and fermentation, p. 292
- (1) Soybean sprouts, p. 295
  - (2) Soybean curd and related products, p. 299
    - i The origin of bean curd, p. 302
    - ii Transmission of tou fu to Japan, p. 317
    - iii Products associated with tou fu, p. 319
    - iv Making of fermented tou fu, p. 326
    - v Comparison of tou fu and cheese, p. 328
    - vi Addendum, p. 331
  - (3) Fermented soybeans, soy paste and soy sauce, p. 333
    - i Ferments for food processing, p. 335
    - ii Fermented soybeans, shih, p. 336
    - iii Fermented soy paste, chiang, p. 346
    - iv Fermented soy sauce, chiangyu, p. 358
    - v Soy fermentations, China and Japan, p. 374
- (e) Food processing and preservation, p. 379
- (1) Fermented condiments, pickles and preserves, p. 379
    - i Fermented meat and fish products, p. 380
    - ii Fermented fish products of East Asia, p. 392
    - iii Fermented fish sauce in ancient Greece and Rome, p. 398
    - iv Pickled vegetables and other victuals, p. 402
  - (2) Chemical and physical methods of food preservation, p. 415
    - i Salting and pickling of vegetables, p. 416

- ii Fu and hsi, dried meat and fish, p. 419
  - iii Preservation of fruits, p. 424
  - iv Cold storage, p. 429
- (3) Production of oils, malt sugar and starch, p. 436
  - i Oil from oilseeds, p. 436
  - ii Malt sugar from cereals, p. 457
  - iii Preparation of starch, p. 461
- (4) Processing of wheat flour, p. 462
  - i Pasta and filamentous noodles, p. 466
  - ii Origin of man-thou (steamed bun), p. 475
  - iii Origin of hun-thun (wonton), p. 478
  - iv Origin and development of noodles, p. 480
  - v Dissemination of noodles in Asia, p. 491
  - vi Noodles and Marco Polo, p. 493
  - vii Production and usage of gluten, p. 497
- (f) Tea processing and utilisation, p. 503
  - (1) Etymology and literature of tea, p. 507
  - (2) Processing of tea, p. 519
    - i Tea processing during the Thang, p. 519
    - ii Processing of Sung cake teas, p. 523
    - iii Processing of loose tea during the Yuan and Ming, p. 528
    - iv Origin and processing of oolong tea, p. 535
    - v Red tea (hung chha) and the black tea of maritime trade, p. 541
    - vi White, yellow, dark, compressed and scented teas, p. 550
  - (3) Tea drinking and health, p. 554
    - i Making and drinking tea, p. 555
    - ii Effects of tea on health, p. 562
- (g) Food and nutritional deficiency diseases, p. 571
  - (1) Goitre (Ying 癭), p. 573
  - (2) Beriberi (Chiao-chhi 腳氣), p. 578
  - (3) Night blindness (Chhüeh mu 雀目), p. 586
  - (4) Rickets (Kou lou 佝僂), p. 588
- (h) Reflections and epilogue, p. 592
  - (1) The wonderful world of the grain moulds, p. 592
  - (2) The uneven flow of food processing innovations, p. 595
  - (3) The evolution of food technology in China, p. 597
  - (4) Nature, technology and human intervention, p. 601
  - (5) Effects of processed foods on health and nutrition, p. 603
- Epilogue, p. 605

<b>BIBLIOGRAPHIES</b>	. . . . .	609
Abbreviations, p. 610		
A. Chinese and Japanese books before 1800, p. 611		
B. Chinese and Japanese books and journal articles since 1800, p. 629		
C. Books and journal articles in Western languages, p. 657		
<b>GENERAL INDEX</b>	. . . . .	675
Table of Chinese Dynasties	. . . . .	734
Romanisation Conversion Table	. . . . .	735

## ILLUSTRATIONS

1	Three Legendary Emperors, Fu Hsi, Shên Nung and Huang Ti, who taught the people Fishing, Agriculture and the Art of Healing. From a Japanese scroll by Seibe Wake, +1798, Veith (1972), cover page.	page 15
2	The staple grains of ancient China: Panicum millet, Setaria millet, Rice, Barley, Wheat, Soybean and Hemp, from Chin Shih Khun Chhung Tshao Mu Chuang (CSKCTMC) 金石昆蟲草木狀: (a) Shu, Panicum millet; (b) Chi, Setaria millet; (c) Tao, Rice; (d) Hsiao Mai, Wheat; (e) Shu, Soybean; (f) Ma, Hemp.	20
3	The Nine Provinces of Ancient China as outlined in the Chou Li (Lin Yin ed. pp. 344-50).	22
4	Food remains discovered in Han Tomb No. 1 at Ma-wang-tui. Hunan sheng po-wu-kuan (1973) II, Pl. 11, p. 9, lower part only.	25
5	Examples of food items recorded on bamboo slips found in Han Tomb No. 1 at Ma-wang-tui. Hunan shêng po-wu-kuan (1973) II, p. 243, Pl. 290.	26
6	Chi Ma or hu ma, sesame; CSKCTMC.	30
7	Kua, melon; CSKCTMC.	34
8	Hu, gourd; CSKCTMC.	34
9	Fêng or Wu ching, Chinese turnip; CSKCTMC.	35
10	Fei or Lai fu, Chinese radish; CSKCTMC.	35
11	Khuei, the mallow; Mōshi Himbutsu Zukō 毛詩品物圖考, 1/23.	37
12	Five Liliaceae; from CSKCTMC: (a) Chiu, leek; (b) Tshung scallion; (c) Hsieh, shallot; (d) Suan or hsiao suan, rocambole; (e) Hu or ta suan, garlic.	41
13	Yü, taro. Painting by Shih Thao, c. +1697; from Fu & Fong (1973), The Wilderness colors of Tao Chi.	42
14	Thao, peach flowers; Mōshi Himbutsu Zukō 毛詩品物圖攷, 3/1.	45
15	Li, plum blossoms; Mōshi Himbutsu Zukō, 3/4.	46
16	Mei, Chinese apricot; Mōshi Himbutsu Zukō, 3/2.	47
17	Li, Chinese chestnut; Mōshi Himbutsu Zukō, 3/6.	50
18	Chên, Chinese hazelnut, Mōshi Himbutsu Zukō, 3/5.	51
19	Phi-pha, loquat. CSKCTMC.	53
20	Carp, Mōshi Himbutsu Zukō, 7/3a.	64
21	Turtle, Mōshi Himbutsu Zukō, 7/5b.	65

- 22 Shang Dynasty pottery *yen* or *hsien* 甗 which consists of a *tsêng* 甑 (steamer) surmounted on a *li*, 鬲 (boiler). From Anderssen (1947), Pl. 90. (1a) *Tsêng Steamer* (1b) *Perforated bottom of Steamer*; (2) *Li Boiler with three hollowed legs*; (3) *Hsien assembled from tseng and li*. . . . . 77
- 23 Steamer from Pan-pho, Shensi: (a) *Crude steamer with boiler and cover: Sian Pan-pho po-wu-kuan* (1972); (b) *Display of steamer assembly at the Pan-pho Museum, c. -4000; photograph H. T. Huang, 1979*. . . . . 78
- 24 Steamer from Ho-mu-tu, Chekiang: (a) *Assembly of steamer, boiler and stove, Ho-mu-tu, c. -5000; CKPJ, 1989* (9), cover; (b) *View of steamer and boiler, Che-chiang shêng wen-kuan-hui, (1978), p. 76, Pl. 3, no. 3*. . . . . 79
- 25 Pottery tripod cauldron, *ting*, 鼎, from Pan-pho. San Francisco Asian Art Museum (1975), Fig. 57, height 15 cm. . . . . 79
- 26 Traditional Chinese stoves, *tsao*: (a) *Clay model from Han tomb. Yunmenghsien wên-wu, (1981), Pl. 10, Fig. 6*; (b) *Traditional tsao seen in Taipei, Taiwan, photograph by H. T. Huang*. . . . . 81
- 27 Three-pronged skewers for *chih* roasting from Chia yu kuan. *Chih Tzu* (1987), p. 7. . . . . 86
- 28 Eastern Han Kitchen scene from Chuchhêng, Shantung. *Jên Jih-Hsin* (1981). . . . . 87
- 29 Chinese bamboo steamers: (a) *Mural with bamboo steamers in a Southern Sung tomb in Kansu. Chhên Hsien-Ju* (1955); (b) *Stove with bamboo steamers in Urumqi, Sinkiang, photograph by Kenneth Hui, c. 1985*. . . . . 90
- 30 Bronze vessel types for serving food and drink. After Buchanan, Fitzgerald and Ronan (1981), pp. 158-9. . . . . 99
- 31 Lacquer tray containing five *phan* plates, two *chih* mugs, one winged-cup and one pair of chopsticks from Han Tomb No. 1 at Ma-wang-tui. *Hunan shêng po-wu-kuan* (1973), II, p. 151, item 160. . . . . 101
- 32 Enlarged section from a mural depicting the Banquet at Hung-Men in a Western Han tomb at Loyang. To the left is a guest holding a horn drinking cup. To the right is a chef roasting a fowl on a large fork over a charcoal fire. Fontein & Wu eds. (1976), Tomb 61, p. 23. . . . . 103
- 33 Gold bowl and ladle from the tomb of Marquis of I. Qian, Chen & Ru (1981), p. 45, Fig. 58. . . . . 106
- 34 Changing styles of spoons from Shang to Yuan, after Chih Tzu (1986b), p. 22: (a) Shang; (b) Western Chou; (c) Spring and Autumn; (d) Warring States; (e) Han; (f) North & South Dynasties; (g) Sui-Thang; (h) Sung-Yuan. . . . . 107



35	Styles of forks, prehistoric to Yuan, after Chih Tzu (1986a), p. 17. For the origin of the forks, cf. Table 10.	108
36	Forks in Eastern Han tombs in Sui-tê, Northern Shensi: (1) Mural, Shensi shêng po-wu-kuan (1958), Fig. 66; (2) Stove model, Tai & Li (1983), Fig. 4-1.	110
37	Eastern Han brick painting of a dining or drinking scene from Chengtu, Szechuan. After Wilma Fairbank (1972).	113
38	Dining scenes from Eastern Han tombs at Liao-yang, Liaoning: (a) From Tomb No. 1, Li Wên-Hsin (1955), Fig. 18; (b) From Tomb No. 2, Wang Tsêng-Hsin (1960), Fig. 3-6.	114
39	First two pages of the Introduction to CSKCTMC, Calligraphy by Chao Chün, from National Central Library, Taipei.	142
40	Vessels excavated from site 14 at Thai-hsi, Kaochhêng, Hopei. Hopei sheng wen-wu yen-chiu so (1985), p. 31, Fig. 20.	151
41	Wine fermentation vessels from Thai-hsi, Kaochhêng, Hopei: (a) Large wêngjar containing 8.5 kg residual mash. Pl. 31 (14:58); (b) Vessel resembling 'General's helmet' for heating or fermenting mash. Pl. 30, no. 3; (14:42); (c) Funnel for transferring or filtering fermentation mash. Pl. 33, no. 2 (14:50).	152
42	Flow diagram for the preparation of superior ferment, after Miao Chhi-Yü ed. (1982), p. 371.	172
43	Preparation of red ferment: washing of rice in a flowing stream. TKKW p. 288.	198
44	Preparation of red ferment: Inoculated cooked rice dispersed on mats and trays TKKW p. 289.	199
45	Preparation of red ferment: Incubation of rice on trays to form red ferment TKKW p. 290.	200
46	Grains of red ferment from Foochow, photograph Chen Jia-Hua.	201
47	Chhêng-teh still, from Chhing-lunghsien, 1976 (9), Figs. 1 & 2. (a) Chin still assembled. Height 41.5 cm, diameter at widest point, 36 cm. (b) Bottom: vessel serving as boiler and steamer. Top: condenser with convex bottom.	209
48	Cross-section of Chhêng-teh still, Lin Yung-Kuei, 1980 (1), Fig. 5.	210
49	Shanghai still, parts (a), (b), (c) photograph Ma Chengyuan: (a) Complete still; (b) Boiler; (c) Steamer, note the perforated bottom.	211
50	Shanghai still, cross-section. Ma Cheng-yuan (1992), 174-83, Fig. 1. First presented at 6ICHSC, Cambridge, 1990.	212
51	Chhu-chou still, cross-section, Li Chih-Chhao & Kuan Tsêng-Chien (1982), Fig. 1.	213

- 52 **Diagram of Hellenistic and Chinese stills; adapted from SCC Vol. v, Pt 4, p. 81, Fig. 1454, (d), (e) and (c<sup>m</sup>), (d<sup>l</sup>).** . . . . . 215
- 53 **Mongolian and Chinese stills (after Hommel) reproduced from SCC Vol. v, Pt 4, pp. 62–3: (upper) Mongolian still; (lower) Chinese still.** . . . . . 216
- 54 **Early 20th-century ‘Hellenistic’ or vase type still, Fang Hsin-Fang (1987), Fig. 1.** . . . . . 217
- 55 **Early 20th-century ‘Chinese’ or pot type still, Fang Hsin-Fang (1987), Fig. 3.** . . . . . 218
- 56 **Brick mural from Szechuan, possibly depicting the distillation of wine, photograph from Rawson ed. (1996), p. 199.** . . . . . 219
- 57 **Traditional Szechuan still in the 1940s, Wang Yu-Phêng (1987), p. 22.** . . . . . 220
- 58 **Diagram of still described in the CCPY, reproduced from SCC Vol. v, Pt 4, p. 113.** . . . . . 228
- 59 **Arabic Retort, photo from the Science Museum, London, +10th century to +12th century.** . . . . . 228
- 60 **Definition of li from Ho Han San Tshai Thu-Huei (+1711).** . . . . . 264
- 61 **Wooden models of Egyptian bread and beer making, British Museum: (a) #45196, model showing female servant stirring mash in the preparation of beer. Jars holding the strained fermenting liquid stand in the foreground. From Asuyt, Middle Kingdom, c. –1900. (b) #40915 model of a large workshop for the preparation of bread and beer. Female servants shown are grinding barley in the background. Others knead dough and some shape dough into loaves. Lightly baked loaves are broken up, soaked with water and fermented in beer making. From Deir el-Bahri. XIth dynasty, c. –2050.** . . . . . 268
- 62 **Origin of wine and beer in the West.** . . . . . 273
- 63 **Origin of Chhü, Nieh and Chiu (Ferment, sprouted grain and wine).** . . . . . 273
- 64 **Sumerian and Chinese depiction of fermentation vats: (a) Pictograph of a Sumerian fermenting vat, after Forbes (1954), p. 280; (b) Oracle inscription for yu 酉 (fermenting); after Hsü Tsung-Shu (1981), p. 563.** . . . . . 276
- 65 **An amphora of the Yangshao culture from Pan-pho, Sian. San Francisco Asian Art Museum (1975), Fig. 28, height 43 cm.** . . . . . 276
- 66 **Brick ferment from the Chiangnan Brewery, Shanghai, photograph HTH.** . . . . . 281
- 67 **Traditional process for making tou fu, from Hung Kuang-Chu (1984a), pp. 58–60: (a) Soaking soybeans, Fig. 1; (b) Grinding soybeans in a rotary mill, Fig. 2; (c) Filtering soybean milk, Fig. 3; (d) Cooking soybean milk, Fig. 4; (e) Coagulating soybean milk, Fig. 5; (f) Pressing of bean curd and processed products, Fig. 6.** . . . . . 304

- 68 Photograph of engraved mural depicting the making of tou fu in Han tomb in Ta-hu-thing, Mi-hsien, Honan, photograph H. T. Huang. . . . . 306
- 69 Drawing of engraved scene on a stone slab from Tomb No. 1, Ta-hu-thing, Mi-hsien, Honan, Chhên Wên-Hua, NYKK (1991), p. 248. . . . . 307
- 70 Photograph of a tou fu pressing box seen in the countryside near Mi-hsien, Honan in the 1980s, photograph Chhên Wên-hua. . . . . 309
- 71 Experimental coagulation of soy milk; left: with boiling, right: without heating, at the Needham Research Institute, 1991, photograph HTH. . . . . 311
- 72 Cake from precipitate from coagulation of unheated soy milk, photograph HTH. . . . . 312
- 73 Flow diagram of soybean curd process, adapted from Ichino & Takei (1975), p. 135. . . . . 321
- 74 Drawing of a hawker selling tou chiang by Yao Chih-Han (Chhing), from the National Palace Museum, Taipei, Taiwan. . . . . 323
- 75 Rubbing of the complete mural referred to on pp. 302–10. From Honan wên-wu yen-chiu-so (1993), Pl. 34. . . . . 331
- 76 Revised sketch of segment 3 of the lower panel. Chhên Wên-Hua (1998), p. 288. . . . . 333
- 77 Preparation of tempeh in the countryside in Bali, photograph HTH: (a) Boiling of soybeans in oil drums; (b) Drained, dehulled soybeans awaiting inoculation with a commercial spore powder; (c) Inoculated soybeans dispensed in flat plastic bags; (d) Bags incubated on trays on a large rack. . . . . 343–4
- 78 Flow diagram for process of making chiang (fermented soy paste) in the Chhi Min Yao Shu. . . . . 350
- 79 Flow diagram of process for making chiang (fermented soy paste) in the Nung San I Shih Tso Yao. . . . . 353
- 80 Flow diagram for the process of making chiangyu (soy sauce) in the Hsing Yuan Lu. . . . . 364
- 81 A traditional soy sauce process – 2nd fermentation showing urns and bamboo covers. Drawing by Hung Kuang-Chu (1984a), p. 108. . . . . 365
- 82 Soy sauce incubating urns and covers – Foochow, 1987, photo HTH. . . . . 366
- 83 Traditional soy sauce process – collecting soy sauce using a cylindrical bamboo filter: (a) Drawing by Hung Kuang-Chu (1984a), p. 108; (b) Urn showing cylindrical bamboo filter, Foochow, 1996, photograph HTH. . . . . 367

84	Traditional soy sauce process in early 20th century – boiler to cook soybeans. Groff (1919), Pl. 1. . . . .	368
85	Traditional soy sauce process in early 20th century – incubation trays for culture of fungi. Groff (1919), Pl. 2, Fig. 2. . . . .	369
86	Traditional soy sauce process in early 20th century – incubating jars with bamboo cover. Groff (1919), Pl. 3, Fig. 2. . . . .	370
87	Traditional soy sauce process in early 20th century – first drawing of product by siphoning. Groff (1919), Pl. 3, Fig. 1. . . . .	370
88	Distribution of fermented condiments in East Asia. The northern area is based on soybean products and the southern area on fish products. After Ishige (1993), Fig. 6, p. 22. . . . .	393
89	Distribution of fish sauce in East Asia. After Ishige (1993), Fig. 4, p. 20. . . . .	394
90	Bronze cooler from the tomb of Marquis of I (c. -400), Hupei Provincial Museum Qian, Chen & Ru (1981), p. 58. . . . .	431
91	Design of an ice house in Fêng-hsiang, Shensi, Spring and Autumn period (c. -500). After Tan Hsien-Chin (1989), p. 297: (a) Diagram of foundation; (b) Reconstruction. . . . .	432
92	Cross-section of an ice storage well in Chi-nan, Capital of the Chhu Kingdom, c. -4th Century. Hupei shêng po-wu-kuan (1980), p. 43. Scale: 30 cm. Identity and relative positions of the objects found in the well: 1, 2, wooden logs; 3, wooden base for other objects; 4-6, 8, 9 a pottery <i>tou</i> (plates with a pedestal); 7, a broken <i>tou</i> ; 10, bowl; 11, broken plough; 12, pottery jar. . . . .	433
93	Sketch of a 19th-century Chinese ice house in Ningpo. Fortune (1853) I, p. 82. . . . .	436
94	Beam press: decoration on Greek Vase –6th century, after Forbes (1956), p. 113. . . . .	438
95	Catonian beam press described in Pliny, after Forbes (1956), p. 114. . . . .	438
96	Oil press from the Wang Chên Nung Shu, ch. 16, p. 126. . . . .	442
97	Oil press from the Nung Chêng Chhüan Shu, ch. 23, p. 576. . . . .	443
98	Steamer and frying pan used in the processing of oilseeds, TKKW, tr. Li Chiao-Phing et al. (1980), Fig. 12-4, p. 320. . . . .	444
99	Trip hammer used to pound shells of nuts to obtain kernels, TKKW, tr. Li Chiao-Phing et al. (1980), Fig. 12-3, p. 319. . . . .	445
100	Grinding of nuts to break shells and obtain kernels, TKKW, tr. Li Chiao-Phing et al. (1980), Fig. 12-2, p. 318. . . . .	446
101	Southern style oil press, TKKW, tr. Li Chiao-Phing et al. (1980), Fig. 12-1, p. 17. . . . .	447
102	Roller-mill powered by two donkeys for pulverising oilseeds. TKKW, p. 97. . . . .	448

103	Rustic oil press carved out of a large tree trunk, photo Hommel (1937), p. 91. . . . .	449
104	Modern oil press based on traditional design. Ministry of Grains (1956), p. 12. (1) Wedge press; (2) Overhead beam connecting the wooden structure; (3) Rolling bar on which the mallet is hung; (4) Lever for turning the rolling bar; (5) Flying mallet; (6) Rod holding the mallet; (7) Additional support for mallet on bar; (8) Movable plank to pull the rope holding the lever; (9) Rope to pull the rolling bar; (10) Lever to lower or raise the movable plank; (11) Wooden support for the operator; (12) Jar for collecting oil; (13) Lower wedge; (14) Upper wedge; (15) Oil cakes to be pressed. . . . .	451
105	European wedge press for making rapeseed oil in the 19th century, after Albrecht (1825), pp. 60–2. . . . .	453
106	Japanese oil press from Okura Nagatsune (1836), tr. and ed. Carter Litchfield (1974), Fig. 2. . . . .	453
107	Ghani – the traditional oilmill of India; from Achaya (1993), cover & p. 42: (a) photograph of a Ghani; (b) cross-section of pit and pestle. . . . .	454
108	Neolithic saddle quern in China, from Sha-wo-li, Hsin-chêng, Honan. Chung-kuo shê-huei kho-hsueh yuan (1983), Pl. 2, Fig. 5. . . . .	463
109	Rotary stone mill, Warring States: Shensi shêng wen-wu kuan-li hui (1966), Pl. 8. . . . .	464
110	Rotary quern, Western Han Chung-kuo shê-huei kho-hsueh yuan etc. (1980), Mancheng Report, Vol. II, Pl. 106, nos. 2 & 3 (cf. description in Vol. I, p. 143). . . . .	464
111	Rotary quern, Eastern Han, Rawson ed. (1996), Fig. 84. Model of a man operating a rotary quern. . . . .	465
112	Dehydrated chiao-tzu (a) and hun-thun (b) found in a Thang tomb near Turfan in 1959. Adapted from Than Chhi-Kuang (1987), CKPJ (11), p. 12. . . . .	479
113	Sliced noodle, chieh mien, photograph S. T. Liu. . . . .	486
114	Hung noodle, kua mien, photograph S. T. Liu. . . . .	486
115	Pull noodle, la mien, photograph Wang Yusheng. . . . .	487
116	Rope noodle, so mien, photograph Wang Yusheng. . . . .	488
117	Press noodle, ya mien, photograph Wang Yusheng. . . . .	489
118	Family of Chinese Pasta Foods (after Ishige). . . . .	490
119	Marco Polo tastes spaghetti at the court of Kublai Khan. From Julia della Croce, <i>Pasta Classica</i> , Chronicle Books (1987), p. 11. . . . .	494
120	A will from the Archives in Genoa, dated February 4, 1279, by soldier Ponvio Bastone in which he bequeathed a basket of 'macheroni', to a relative. Courtesy of the Spaghetti Museum, Pontedassio, Imperia, Italy. . . . .	495

121	<i>Camellia sinensis</i> (L) O. Kuntze, from Ukers (1935) I, front page.	504
122	First two pages of Lu Yü's <i>Chha Ching</i> (Classic of Tea) from a Ming edition?	514
123	Design of seals on Sung tribute teas, Chhên & Chu (1981), pp. 70-1. 1a, 1b.	526
124	Picture of a Northern Sung tea house, from <i>Chhing-ming shang ho thu</i> 清明上河圖 (A City of Cathay), Pl., Scroll Section v, National Palace Museum, Taipei (1980).	528
125	Rolling tea leaves with feet in China, from Ukers (1935) I, p. 468.	535
126	Map of Southeast China showing the black tea country of Wu-I in Fukien (A) and the green tea country of Sing-lo in Anhui (B). In the 18th and early 19th century, tea produced in these regions was transported southwards through Kiangsi all the way to Canton for shipment in the overseas trade.	545
127	Chinese style implements for processing tea in India, from Ukers (1935) I, p. 464.	550
128	The genealogy of the major teas of China.	551
129	Tea utensils from <i>Chha Chü Thu Tsan</i> 茶具圖贊, pp. 5-27; a-1, +1269. Altogether twelve pictures, from Chhên & Chu (1987), pp. 96-119; Cf. also Ukers (1935) I, pp. 16-18. (1) Bamboo basket for drying tea; (2) Wood anvil and iron mallet to mould the tea into cakes; (3) Iron grinding boat; (4) Stone grinding mill; (5) Gourd as ladle for measuring water; (6) Sieve to separate coarse from fine tea; (7) Brush for removal of dust; (8) Lacquer cup with holder; (9) Porcelain tea bowl; (10) Porcelain tea pot; (11) Bamboo brush for washing pots; (12) Towel for cleaning cups.	558
130	Preparation of kung-fu tea, Taipei, photograph HTH.	562
131	Chemical formulae for tea catechins and oxidised catechins.	567
132	Trip hammers activated by human foot for polishing rice. TKKW, p. 91.	583
133	A bank of trip hammers activated by water power. TKKW, p. 92.	584
134	The Wonderful World of the Grain Moulds. Processed foods related to the Mould Ferment – <i>Chhü</i> 麴.	594
135	Evolutionary history of the rotary quern and its applications.	598
136	Evolutionary history of the Mould ferment and its applications.	600

## TABLES

1	The staple grains and major livestock of ancient China . . . .	page 21
2	Vegetables in ancient China cited in the Shih Ching and Li Chi and found among archaeological remains in Han tombs . . . . .	33
3	Fruits in ancient China cited in the Shih Ching and Li Chi and found among archaeological remains in Han tombs . . . . .	44
4	Support staff for keepers of various livestock as described in the Chou Li	56
5	Species of fish cited in the Shih Ching . . . . .	62
6	Methods of cooking revealed in Chou and Han classics . . . . .	70
7	Comparison of ancient and modern Chinese methods of cooking . . . . .	88
8	Seasonings used in ancient and modern Chinese cookery . . . . .	95
9	Serving vessels for food and drink in ancient China . . . . .	100
10	Archaeological finds of forks in ancient China . . . . .	108
11	Ancient classics as sources of culinary information . . . . .	117
12	Contents of the Chhi Min Yao Shu . . . . .	123
13	Food canons and recipe books in late mediaeval China . . . . .	127
14	Food canons and recipe books in premodern China . . . . .	129
15	Wine classics of the Sung and Ming dynasties . . . . .	133
16	Mediaeval and premodern works on <i>Materia Dietetica</i> . . . . .	135
17	Fermentation of a Chou wine and modern Shao Hsing wine . . . . .	164
18	Names of wines produced by the Chou Chinese . . . . .	165
19	Types of ferments made in Han China . . . . .	167
20	Methods for preparing ferments in the Chhi Min Yao Shu . . . . .	170
21	Yield of alcohol in wine fermentations in the Chhi Min Yao Shu . . . . .	180
22	Ferments described in the Pei Shan Chiu Ching . . . . .	185
23	Fermentation of wine in the Pei Shan Chiu Ching . . . . .	186
24	Dimensions of the Chin bronze steamer-still . . . . .	210
25	Common medicated wines noted in the Food and Drug literature . . . . .	236
26	References to dairy products in the Chinese food literature . . . . .	256
27	Comparison of ancient fermentation processes for making alcoholic drinks . . . . .	275
28	Types of traditional Chhü ferments made in China today . . . . .	280
29	Family of products related to soybean curd . . . . .	322

30	Preparation of tou fu and cheese . . . . .	329
31	Nutrient value of tou fu versus cheese . . . . .	330
32	Processes for making various types of chiang . . . . .	356
33	Usage of soy condiments in food recipes from the Han to the Chhing dynasties . . . . .	372
34	Basics of Chinese and Japanese soyfood fermentations . . . . .	378
35	Chiang from animal products in the Chhi Min Yao Shu . . . . .	381
36	Making of fish and meat preserves, Cha, in the Chhi Min Yao Shu . . . . .	385
37	Products from fermentation of salted fish in East Asia . . . . .	395
38	Making of pickled vegetables, Tsu, in the Chhi Min Yao Shu . . . . .	406
39	Methods of food preservation involving microbial action . . . . .	409-10
40	Salting of vegetables from the Sung to the Chhing dynasties . . . . .	418
41	References to vegetable oils in the Chhi Min Yao Shu . . . . .	440
42	Comparison of European, Chinese and Japanese processes for the pressing of vegetable oils . . . . .	455
43	Recipes for making ping (pasta) in the Chhi Min Yao Shu . . . . .	470
44	Recipes for cooking gluten from the Yuan to the Chhing dynasties . . . . .	502
45	World production of tea in 1950 and 1988 . . . . .	505
46	World consumption of tea per capita, 1984-1987 . . . . .	505
47	The tea books (Chha Shu) of China . . . . .	516
48	Implements used in the processing of tea listed in the Chha Ching . . . . .	521
49	Processing of Sung tribute tea at Pei Yuan . . . . .	524
50	References to the processing of tea in Ming tea books . . . . .	530
51	Ming system for processing tea . . . . .	533
52	Comparing the traditional processing of red, oolong and green teas . . . . .	537
53	Origin of the major red teas in the China trade in the late 19th century . . . . .	544
54	Implements used in making tea in Lu Yü's tea classic . . . . .	556
55	Tea utensils used by Emperor Hui Tsung . . . . .	559
56	Traditional Chinese views on the effects of tea . . . . .	565
57	Garway's First Tea Broadside (+1660) . . . . .	566
58	Comparison of flavanol compounds in the three major teas . . . . .	568
59	Symbolic correlations of Wu-Hsing categories in heaven, earth and man . . . . .	572
60	The development interval of selected processed foods initiated during the Han . . . . .	595
61	Summary of processed foods derived from grains . . . . .	604



## AUTHOR'S NOTE

This book may be said to have had its genesis in two memorable events that I experienced in China more than fifty years ago. The first was an enforced holiday I had for several months in the fall of 1942 in my ancestral village, Hothang 鶴塘, and the second a delightful encounter in the spring of 1943 with the eminent scholar, Shih Shêng-Han 石聲漢. Hothang is a tiny village about seventy kilometres north of Foochow 福州. It seemed a world away from the bustling city of Hong Kong where I was a research student less than a year earlier. My comfortable life there was shattered when the Japanese suddenly attacked on the morning of 8 December 1941. After Hong Kong fell on Christmas day I was cut off from my family in Malaya and left without any means of support. I realised that the best thing for me to do was to leave for China as soon as possible. The opportunity came early in February, 1942, when I made my way, with the help of friends, through the New Territories and crossed the border into Free China. My original plan was to travel to Hothang to visit my paternal grandmother, but the plan encountered a delay along the way. I stopped by at Amoy University in Changting 長汀 to deliver a message to Professor Arthur Lee from his niece in Hong Kong who was a classmate of mine.<sup>1</sup> He kindly persuaded the University to offer me a job as an instructor in the Chemistry Department, which I gratefully accepted.

After the semester was over I continued my journey to Hothang, where I had a joyous reunion with my grandmother and other relatives. While in Changting I had met a couple of field officers of the Chinese Industrial Cooperatives (CIC) who indicated to me that they were in need of technical personnel in Szechuan and Kansu. I expressed my interest to serve in their organisation. In July I went to Foochow to visit the Anglican Bishop of Fukien, C. B. R. Sargent, who was the teacher of a close friend in Hong Kong.<sup>2</sup> When I returned to the village there was a letter from CIC headquarters asking me if I would be willing to accept an appointment as a research technician in Chengtu. I was delighted and replied that I would. I immediately resigned from Amoy University, fully expecting to be on my way to Szechuan within a couple of months. But the wheels of bureaucracy grinded ever so slowly. I waited and waited as months went by.

Hothang was a small village with probably no more than a couple of a hundred inhabitants. It had one narrow street paved with rectangular blocks of stone, flanked by hills on one side and a rivulet on the other. A series of steps down the street from my grandmother's house would lead to the market square in the centre

<sup>1</sup> Arthur Lee was a Chinese Australian who came to Amoy to teach English. He married one of his students and stayed on to be Professor of English at the University. I am deeply grateful to him and Mrs Lee for their hospitality during my stay in Changting.

<sup>2</sup> Before he was consecrated Bishop of Fukien, Christopher Sargent was the Headmaster of the Diocesan Boy's School in Hong Kong. Unfortunately, he died from pneumonic plague on 8 August 1943.

of the village. Going up the hill in the other direction lies the Ancestral Temple, a building in traditional style with elegant sloping roofs. The only other public building in the village was the Christian Church on the far side of the market square.

Having virtually nothing to do, I spent a great deal of time observing the numerous food processing and culinary activities involved in the preparation of the meals I ate everyday. The primary staple in the village was, of course, rice, coarse white rice and red rice. For breakfast, rice was boiled gently in plenty of water and allowed to simmer into a congee<sup>3</sup> in one of the two large woks that sat on the stove in the kitchen.<sup>4</sup> For lunch and dinner, rice was boiled and the semi-cooked grains steamed in a bamboo steamer.<sup>5</sup> The wash water was usually fed to the pigs. To go with the congee we had roasted peanuts, pickled vegetables, salted duck eggs, fermented soybeans, fermented beancurd, and as a special treat deep fried crullers (*yu thiao* 油條) when they were available from the market. The steamed rice would be accompanied by beancurd, salted fish of various kinds, salted or pickled vegetables, fresh leafy vegetables or beans, dried seaweeds, and, on rare occasions, bacon, sausages, eggs, pork, chicken or fish. Vegetables and meat were usually stir-fried with lard or peanut oil, flavoured with soy sauce, fish sauce, salt, rice wine, vinegar and sesame oil. We drank tea during the day, and occasionally wine in the evening.

For fresh produce we relied on what we could get daily in the market at the centre of the village, which served as a gathering place for the people of several neighbouring villages as well as Hothang. I remember stalls selling various kinds of vegetables, fruits, bean sprouts, peanuts, chickens and occasionally fish. The latter two would be sold live. Depending on the season, I might also find hawkers peddling soft beancurd custard (*tou fu hua* 豆腐花), malt syrup candy (*mai ya thang* 麥芽糖), deep fried crullers (*yu tsa kui* 油炸鬼), and pastries made of glutinous rice (*no mi kao* 糯米糕). Among the shops that lined the sides of the square, several were trading in food products such as rice, wheat flour, salt, loose brown sugar, oil, wine, vinegar, soy sauce, fish sauce and brown sugar blocks. Three were of particular interest to me: the butcher, the beancurd shop and the noodle maker. The butcher probably slaughtered a pig every day. Sections of the animal would be hung on hooks so that the customer could easily decide which part of the pig and how much of it he wanted. The parts in greatest demand were the tenderloin, spareribs, liver, brain and kidney. Occasionally, goat meat might also be on sale, but no beef was available during my stay.

I must have spent hours watching the processing of soybeans into curds which were then pressed into blocks of *tou fu*. The process was identical to that shown in the Eastern Han mural from Ta-hu-thing, Mi-hsien down to the shape of the rotary quern for grinding the beans and the square wooden press for pressing the curds.<sup>6</sup>

<sup>3</sup> The significance of congee in the origin of grain fermentations is discussed on p. 260.

<sup>4</sup> The traditional Chinese stove is described on p. 80, and shown in Figs. 26a,b. Quite often chunks of sweet potato would be cooked together with rice in the congee.

<sup>5</sup> For a description of the steamer cf. pp. 76–82 and Figs. 23, 24, 26, 29.

<sup>6</sup> The Eastern Han mural is described on pp. 86–7.

Most of the beancurds produced were sold as blocks of fresh *tou fu*. Portions were pressed further and salted as *tou-fu-kan* 豆腐干 (dried beancurd). In the summer some of the fresh curds would be mixed with brown sugar water and sold as a delicious soupy custard (*tou-fu-hua*). The butcher and the beancurd shop were the busiest places in the village. They were usually sold out by midday. The noodle maker, however, remained open until early evening. He kneaded his dough with a long rolling pin until it was a thin sheet about two feet wide and several feet long. The sheet would be folded into a block and then sliced with a big cleaver. The long filaments of sliced noodle (*chhieh mien* 切麵) were boiled, strained, cooled on a round mat and sold.<sup>7</sup> The shop also served as a mini-restaurant. I often indulged myself with an afternoon snack of stir-fried noodles, noodle soup and on rare occasions wonton and noodles.

There was another shop making wheat flour foods closer to our house. This one made very fine noodles, called *kua-mien* 掛麵 (hung noodle) that is still a specialty of Fukien. The dough is pulled into banks of fine threads and then hung on wooden racks in the open to dry. Poles with racks were installed on the vacant lot next to the shop. On fine days we would see a forest of hung noodles being dried between the racks.<sup>8</sup> It was quite an amazing sight. The dried noodles were folded into bunches, and sold. This same shop also made a bun called *kuang-ping* 光餅 (bright bun) unique to northern Fukien. It is round and has a hole in the middle. It looks and tastes just like a bagel, except that it is smaller. What seemed to me especially interesting is the oven used to bake it. It is simply a large urn enclosed in a large block of clay. Charcoal is burnt at the bottom and the pieces of dough baked on the side of the urn.<sup>9</sup> Considerable skill is needed to collect the bun as soon as it is baked so that it does not fall into the fire. This shop also made moon cakes for the Autumn Festival.

The two most engrossing food processing operations could be seen taking place right next door. The family ran a small workshop making wine from steamed rice with the aid of the red *ferment* (*hung chhui* 紅麴).<sup>10</sup> The *ferment* was purchased locally, and the rice was the same as that we ate for lunch or dinner. There were urns containing wine fermentations at varying stages of maturity. When ready the mash was placed in a cloth bag and pressed in a square box under a block of stone. The red liquid was allowed to settle and then decanted into little urns and sealed. There were two major uses for the red residual mash. It was a popular flavouring agent for cooking chicken, pork and fish. It imparted a brilliantly red colour and a delicious flavour to the food. It was also extensively used as a preservative and pickling agent for meat, fish and vegetables, such as Chinese cabbage, turnips and ginger.<sup>11</sup> The young ginger root pickled in this way was absolutely delectable.

<sup>7</sup> The making of sliced noodles is discussed on p. 484, and illustrated in Fig. 113.

<sup>8</sup> The drying of *kua mien* is shown in Fig. 112.

<sup>9</sup> This is an example of the tandoor oven, seen all across Central Asia from Iran to the West and Sinkiang to the East.

<sup>10</sup> The making of red *ferment* and red wine is discussed on pp. 192–202.

<sup>11</sup> The use of the red wine residues as a preservative is discussed on pp. 302, 411, 413.

Next to the 'winery' is another workshop which made fermented soybeans (*shih* 豉) and soy sauce (*shih yu* 豉油).<sup>12</sup> To prepare *shih* soybeans were boiled, steamed, cooled, mixed with a small amount of previously moulded beans, spread out in an urn and allowed to become mouldy. The moulded beans were then incubated in a minimal amount of brine until it became dark brown. The *shih* was used mainly as a relish for breakfast. To make soy sauce, the cooked beans were mixed with flour and allowed to become mouldy as before. They were then incubated with a liberal amount of brine, and this time, it was the liquid that was collected. The solids were practically all disintegrated. The residue was fed to the pigs. Both the wine and the soyfoods prepared were sold through local shops.

Up the hill just below the Ancestral Temple was a large building called the Tea Trade Centre (*chha hang* 茶行). In it were a series of stoves with large woks for stir-frying tea leaves. In the late 19th and early 20th century this region used to be a flourishing centre for producing black tea (in Chinese red tea or *hung chha* 紅茶) for export.<sup>13</sup> But the industry declined when India replaced China as the world's major producer of black tea. Now the Trade Centre just processed a small amount of green tea for local consumption. The most impressive piece of equipment there was a giant wedge press made out of a single large tea trunk.<sup>14</sup> It was being used to press oil from tea seeds.

Soon it was October. The rice plants in the fields were ready for harvest. I went out several times at dawn to the fields owned by the family to watch how the plants were cut, threshed, and the grains collected. They were carried back to the village, dried on large mats, decorticated in a clay quern (*lung* 礮), and winnowed in a machine to separate the kernels from the chaff. The kernels were carried to a mill by a stream nearby and polished in a series of trip hammers powered by a large water wheel just like the one shown in the *Thien Kung Khai Wu* 天工開物.<sup>15</sup>

I was impressed by the ingenuity displayed in the processes I saw. It seemed to me they all had a rational, scientific basis. The cooking of the rice allowed the starch to swell and become easily digestible not only to humans but also to microorganisms. The kneading of the wheat flour dough generated gluten which endowed it with flexibility and plasticity. But I marvelled at the extent to which a piece of dough could be stretched lengthwise until it reached almost silken dimensions. The grinding of soybeans in water to form a milk-like emulsion was presumably a natural consequence of the properties of the proteins and fats in the bean. What intrigued me most were the fermentations of grains into wine and soybeans into soy sauce. They were rather complicated processes that required a high level of understanding and technical skill. What is the scientific basis of these processes? How did they come

<sup>12</sup> The preparation of fermented soybeans and soy sauce is treated on pp. 336–74. Soy sauce is called *shih yu* (sauce from fermented soybeans) in Fukien and Kuangtung but *chiang yu* (sauce from fermented soybean paste) in most parts of China.

<sup>13</sup> The origin of black tea, called red tea in Chinese, is discussed on pp. 541–9.

<sup>14</sup> The Chinese wedge press is discussed on pp. 441–51. Cf. also *SCC* Vol. iv, Pt 2, p. 206 and Fig. 463.

<sup>15</sup> *TKKW*, pp. 79–92. For a discussion of the machines cf. *SCC* Vol. iv, Pt 2, pp. 151–5; 176–95.

about? What were their origins? How long ago were they discovered? When I asked the people doing the work, the answer was always that they had been around a long time, or that they were the legacy of Shên Nung, the legendary ruler who discovered Agriculture and Medicine.

As it turned out, the answer to some of the questions came sooner than I would have thought possible. By mid-November I had received all the necessary travel documents and a travel advance from the CIC. My grandmother made me a batch of malt candy from barley (or wheat) malt and steamed rice as a going away present. I left Hothang in early December<sup>16</sup> and travelled through Fukien, Kiangsi, Kuangtung, Kuangsi, Kweichow and Szechuan, eventually reaching Chengtu in early February, 1943. But before I had a chance to settle down in my new position, I received a letter in April from Joseph Needham who had recently arrived from England and was setting up a Sino-British Science Cooperation Office in Chungking, asking me if I would be interested in joining his organisation as his secretary and interpreter. After suitable negotiations with the CIC I was hired as his secretary in May and we started on our first peregrination together. From Chengtu we drove to Loshan 樂山 where our host was Wuhan University. There we met Shih Shêng-Han 石聲漢, Professor of Plant Physiology, who had ingeniously built all kinds of apparatus out of the simplest materials available both for research and teaching purposes.

After a week in Loshan we went on to Wu-tung-chhiao 五通橋, the centre of a chemical industry complex where we visited the Huang Hai 黃海 Research Laboratory, which had a programme on improving the strains of fungi used in the saccharification of grains for conversion to alcohol. It was there that I had my first view, under a microscope, of the myceliae of *Aspergillus* species isolated from the Chinese ferment (*chhü* 麴). Our next stop was Lichuang 李莊 which could only be reached by boat. We were to sail first on a salt transport boat down the river to Iping 宜賓, and then by steamer to Lichuang. To ensure that there would be no hitch, Shih Shêng-Han decided to come along as our guide. It turned out that his presence was invaluable, since the salt boat developed unexpected trouble after the very first day. Shih negotiated with the owner of a small boat, and we hired him to take us to Iping. But we missed the steamer there and continued the trip in the small boat all the way Lichuang.<sup>17</sup>

<sup>16</sup> I did not see Hothang again until January 1996, fifty-five years later. To my amazement it has become a bustling little town with several paved streets, motor vehicles moving to and fro, multistorey houses built of concrete and electric lights in the buildings. Our ancestral house where I stayed in 1942 still stands. It happens to be located in the small section of the old street that has been marked for preservation. The Ancestral Temple remains in good condition. It now doubles as a nursery school and kindergarten. The old Tea Trade Centre has been torn down. The picturesque mill with its huge water wheel has been dismantled. A new town hall stands on the site of the old Christian Church, which has been rebuilt on a location outside of town. The most striking impression I got during my brief visit is that everyone I met (which means practically everyone younger than I) spoke very good Mandarin (at least compared to me), whereas in 1942 few people spoke any Mandarin at all. Coupled with my experience in Taiwan, it is clear that there the search for a common spoken language for all China has been successfully supported by both the Communists in China and the Nationalists in Taiwan, cf. Ramsey, S. Robert (1987).

<sup>17</sup> For details of our boat trip see H. T. Huang (1982), pp. 44–6.

Shih Shêng-Han had received his doctorate from the Imperial College, London and spoke English fluently. He had a wry sense of humour and soon he and Needham were exchanging jokes in English. Conversation flowed easily and continuously during the two days that we were together cooped up in a small space. We talked about all sorts of things but the topic that received the most attention was the History of Science and Technology in China. Shih seemed to be a fountain of information on the origin of the traditional agricultural and food processing technologies of China. I quickly seized the opportunity and plied him with questions on the science and the history of the food processes that I had seen and pondered on in Hotang half a year ago. I learned that, indeed, many of them had had a long history. In fact, detailed descriptions about most of them can be found in a 6th century compendium called the *Chhi Min Yao Shu* 齊民要術 (Important Arts for the People's Welfare).

Shih Shêng-Han stayed on with us in Lichuang for two days. He and I shared a bedroom in the guest house of Tungchi 同濟 University. Our conversations on traditional Chinese food processing continued deep into the night. He patiently answered all my questions. By then I had learned that he was not only a competent scientist, a noted scholar of Chinese classics but also a renowned calligrapher.<sup>18</sup> Obliging he wrote down the two poems he had introduced us to during our memorable boat trip on two small scrolls, which I later mounted and framed. They have adorned my study for many years and remained a constant source of inspiration as I laboured in the myriad tasks involved in the writing of this book.

Now, as I look back across a span of half a century, I realise how fortunate I was to have been a principal participant in these memorable events which have in recent years assumed a renewed importance as I laboured to complete the present volume. For my sojourn in Hothang enabled me to witness the practice of traditional Chinese food processing methods in the context of daily living in a small village before the onslaught of modern technology. And my encounter with Shih Shêng-Han gave me an opportunity to discuss the scientific basis and historical background of this technology with a foremost scholar of the field. It was the memory of these events at the back of my mind<sup>19</sup> that encouraged me to accept, with little hesitation, Joseph Needham's invitation in late 1984 to be the collaborator responsible for the writing of Section 40, Biochemical Technology, of his *Science and Civilisation in China* (SCC) series.

As Needham reiterated in his invitation, the focus of this Section should be the scientific basis and historical background of the fermentations and food processing

<sup>18</sup> An example of Shih's calligraphy still hangs in the Needham Research Institute, Cambridge.

<sup>19</sup> Actually, the memories of those two events were never too deeply buried at the back of my mind. I spent many years in my professional life as a research scientist and research administrator in the fermentation and food industry in the US. I was familiar with the production and application of fungal enzymes used in food processing in the US including amylases, proteases, pectinases, lipases and microbial rennet. What is not generally known is that most of the organisms involved, such as *Aspergillus*, *Rhizopus* and *Mucor* species, were first isolated from the ancient ferment 麴 (Chinese *chü* or Japanese *koji*), the principal agent used in Chinese and Japanese fermentation processes.

technologies that are the mainstay of the Chinese dietary system. Although much has been written about Chinese cuisine and food culture, very little has been written by European scholars on the technology of Chinese processed foods. As a result, the translation of Chinese food terms into English is often highly misleading.<sup>20</sup> He hoped also, that along the way, we would be able to satisfy his personal curiosity about the origin and development of a number of unusual food products that he had encountered during his travels in China in the early 1940s, such as the red *ferment* that colours chicken and fish a brilliant red in Foochow, the *fu ju* (fermented bean curd) that endows the Buddhist's vegetarian stew with a unique flavour in Kuangtung, the delectable aroma of the distilled wine in Kweichow, the soy milk that we consumed every morning at breakfast in the Northwest, and the 'cream' that made possible the delicious 'creamed cauliflower 奶油菜花' that soothed our spirit as we struggled with endless calamities suffered by our truck along the panhandle in Kansu.

As originally conceived in the master-plan for *SCC* published in 1954,<sup>21</sup> and revised in 1979, Section 40 was to consist of one major subject, Fermentation (i.e. the conversion of grains to alcoholic drinks), and two minor ones, Food Technology (i.e. the production of processed foods from soybeans and grains), and Nutrition (with emphasis on nutritional deficiency diseases). Two revisions of the plan were discussed and adopted in the first few years after I started to work on the project. Firstly, Food Technology was greatly expanded since it became clear, based on the wealth of material that Needham and Lu Gwei-Djen had already collected, the space allotted to this subject in 1979 was woefully inadequate. Secondly, processing and utilisation of tea were transferred from Section 42 into this Section.<sup>22</sup> After all, tea and wine are the two principal beverages of the Chinese dietary system; thus the processing of tea should be discussed in the company of the technology of wine. Additional adjustments and revisions proved to be necessary in response to the recommendations of anonymous readers who evaluated the preliminary draft on behalf of the Publications Board of the Needham Research Institute. As it turns out, the book that finally emerges is an enlargement of the 1954 master-plan, that is to say, it contains a major section on Fermentations and a minor section on Nutrition, except that another major section, that on Food Science is added.

The book covers almost all aspects of the traditional food processing technologies that I had witnessed in 1942. It also includes the processing of foods that I had encountered as part of my diet in Hothang, but that were not produced

<sup>20</sup> A sentiment shared by David Knechtges (1986), p. 63, who points out that 'exacting philology and careful science' are needed to render a Chinese food term into English.

<sup>21</sup> See *Science and Civilisation in China (SCC hereafter)* Vol. 1 (1954), pp. xxxv–xxxvi. This plan was revised in the report on *Status of the Project*, (1979), Cambridge University Press, p. 32.

<sup>22</sup> Tea was originally a topic in Section 42, Agro-Industries, which was the responsibility of Christian Daniels. Under the reorganisation Tea was split into two parts. Processing and utilisation became a chapter in this work. Horticulture and genetics were assigned to the Section 38 as a continuation of the volume on Botany, which is being prepared by Georges Metailie. I regret the inconvenience this must have caused Professor Daniels, whose excellent contribution to Section 42 was published in 1996.

locally. These were imported from neighbouring counties, for example, fish sauce, pickled fish, salted fish, salted pork and cured meat products. As I began the project I was excited by the prospect of rediscovering or refining answers to the many questions on Chinese processed foods that I had asked myself years ago and which were reiterated by Joseph Needham. How did they come about? What were their origins? What are the scientific bases of the technologies? How do they compare with processed foods developed in the West? But new questions had already entered my mind even before the work began. To what extent were Chinese processed foods transmitted to her neighbours? Did Chinese food technology have any influence on the development of the food systems of the West? What are the nutritional value of the processed foods? What is the nutritional efficacy of a traditional Chinese diet?

To provide an adequate background for the consideration of these questions, the book begins, in the Introduction, with a survey of the food resources in ancient China, and an account of how the food materials were prepared, cooked and presented for consumption. This is followed by a review of the Literature and Sources used in this study. From there we begin our exploration of traditional Chinese food processing technology. Our first topic is Fermentation technology, the production of alcoholic drinks in their various manifestations, wines from grains, red wine, distilled wine, medicated wines, and wines from fruits, honey and milk. Included also is a comparison of the very different technologies for converting grains into alcoholic drinks in East Asia and in the West, and an explanation of the reason for this divergence. The account ends with the production of vinegar from wine. In the next topic, we go on to the processes by which soybeans are converted by biological, physical, chemical or microbial methods into palatable and nutritious food products. Perhaps the most striking impression one gets from these accounts is the remarkable role a culture of common grain moulds, of the families *Aspergillus*, *Rhizopus* and *Mucor*, known as *chhü* 麴 has played in the processing of foods in China, a situation without parallel among the food cultures of the world. The influence of the grain moulds is seen even in the next chapter when we consider various technologies for the Processing and Preservation of a variety of foodstuffs, such as the making of pickled meat and vegetables, fermented fish sauces, salted fish and meat, fruit preserves, vegetable oil, malt sugar, starch, noodles and other pasta foods, gluten and the use of cold storage in food preservation. In some of the examples, the role of the grain moulds is augmented by the activity of lactic acid bacteria, which are, of course, well known in the food technology of the West. The next topic is the processing of tea, which has undergone a series of changes since it was first prepared as a drink before or during the Han Dynasty. What came as a complete surprise is the discovery that the tea most widely consumed today, i.e. fully fermented tea, known as 'black tea' in the West but 'red tea' (*hung chha* 紅茶) in China, did not exist until about 1840. What was called 'black tea' in maritime trade by tea merchants of the East India Company from about 1720 to 1840 was actually a partly fermented or *oolong* tea. The discussion on tea ends with a consideration of the



effects of tea drinking on health as understood by the Chinese, some of which have turned out to be quite acceptable on the basis of modern scientific studies. The chapter on Nutrition is focussed on the natural history of nutritional deficiency diseases in China and how they were treated by dietary means. The volume concludes with a number of Reflections on the overall process of discovery, development and utilisation in food technology in China, its failures as well as its triumphs, and how the grain moulds have surreptitiously crept their way into the technology used today in the manufacture of many familiar processed foods seen on modern grocery shelves around the world.

Thus, in a nutshell, this work deals mainly with developments in Fermentations and Food Science with a brief foray into Nutrition during the historical period in China from antiquity to the 19th century. A great deal of information is available in the classical and mediaeval literature, although much of it is widely scattered and not easily accessible. But for two issues which Needham had raised in our discussions, I have had to explore developments far back into the prehistoric past. For these I had no choice but to rely entirely on the archaeological record which has shifted significantly through new finds even during the span of time that this work was undergoing preparation. The first is the fermentation of cereal grains into alcoholic drinks, East and West. Why did the Chinese replace sprouted grains by a culture of grain moulds as the saccharifying agent in the conversion of grains to sugar? Why did the West fail to discover the bountiful saccharifying activity of the grain moulds? It is impossible to discuss this issue without considering how grains were processed in China and the West, respectively, in the early Neolithic age at the dawn of the agricultural revolution. The second is why milk and milk products did not become a staple part of the diet in China even though dairy animals were reared by the Neolithic Chinese? It is impossible to discuss this problem without going back to the early stage of animal domestication and the origin of a nomadic pastoral way of life, West and East. Although I have included an answer for only the first of the two issues in this work, the forays into the distant past have reinforced the notion that many of our cherished dietary practices, habits and attitudes may have had a longer history than is generally recognised.

This volume is dedicated to the memory of three pioneers in the study of Chinese food science, culture and nutrition. My debt to Shih Shêng-Han needs no reiteration. It is my misfortune that I never had a chance to meet Shinoda Osamu 篠田統 while he was alive. The depth and breadth of his scholarship and the freshness of his ideas never failed to impress me as I delved into his wide-ranging contributions to the field. A translation of a collection of his essays, under the title, *Chung-kuo shih-wu shih yen-chiu* 中國食物史研究 (Studies on the History of Chinese Foods), has been a constant companion soon after it was published. I sorely missed the support and counsel of Lu Gwei-Djen that I had enjoyed during the last few years of her life. She took great pains to give me useful answers to the many questions I had put to her, and continued to feed me material that she thought would be of interest for this Section even in the last few months before she passed away.

Many friends and colleagues have contributed to the substance of the present volume. Those who have read parts of it in draft form and provided comments and advice and steered me to publications that I had missed are listed at the end of this note. But I do need to single out for special thanks several colleagues from this list who have put in a large amount of time and effort to help me in this endeavour. The late Wu Te-To 吳德鐸 of Shanghai went out of his way to provide me with a valuable array of pertinent publications from China, including all the newly annotated editions of the classics of food literature published in the last two decades by Commerce Publishers, Peking. From 1984 to his untimely death in 1992 we had exchanged a steady stream of letters on many issues, including the origin of distilled wine, relevant to the content of this volume. Ishige Naomichi 石毛直道 of Osaka generously sent me many of his books and publications on food culture and technology in East Asia as well as reprints of articles from the Shinoda Collection at the National Museum of Ethnology. He was my principal source of information and advice on fermented fish products and filamentous noodles. He graciously answered all my questions, some of which must have required a considerable amount of his time. William Shurtleff of Lafayette, California, was my principal consultant on the processing of soybeans. He has collected probably the world's largest data base on soyfoods, and was ever ready to search through it for information I needed. Many useful publications were the gift of Hung Kuang-Chu 洪光注 of Peking and Françoise Sabban of Paris. Finally, E. N. Anderson of Riverside, California, kindly read through the entire draft with a fine toothcomb, and offered hundreds of ameliorations and corrections.

Many other colleagues who had not read any part of the draft had also provided me with valuable publications and helpful advice. Foremost among them is Hu Daojing 胡道靜 of Shanghai. It was through his good offices that I obtained a copy of Miao Chhi-Yü's admirable edition of the *Chhi Min Yao Shu* from the Agricultural History Centre of Nanking University. Others in this group are Li Jingwei 李經緯, Xi Zezong 席澤宗, Zheng Jinsheng 鄭金生, Zhong Xiangju 鐘香駒 and Zhou Jiahua 周嘉華 of Peking; Cao Tianqin 曹天欽, Xie Xide 謝希德, Ma Chengyuan 馬承源, Ma Boying 馬伯英 and Qian Wen 錢雯 of Shanghai; Zhong Xiangchong 鐘香崇 of Loyang; Chen Wenhua 陳文華 of Nanchang; Chen Jiahua 陳家驊 of Fuzhou; Y. C. Kong 江潤祥 of Hong Kong; Tanaka Tan 田中談 of Osaka; Ho Peng Yoke 何丙郁 and Delwen Samuel of Cambridge, England; Ti Li Loo 陸迪利 and Ann Gunter of Washington, DC; Tai-Loi Ma 馬泰來 of Chicago; Hui-Lin Li, Naomi Miller and Carmen Lee of Philadelphia; Frank Hole and Anne Underhill of New Haven; David Heber of Los Angeles, Joseph Chang of Simi Valley and Ida Yu of San Leandro, George Amelagos of Gainesville; and Cyril Robinson of Carbondale, Illinois. To this list I should add the colleagues who have helped me with translations from the Japanese, namely Rao Pingfan, Chen Jiahua, Ushiyama Terui 牛山代輝, Lowell Skar, Ishige Naomichi and Ueda Seinosuke. Jeon San Woon performed the same service for Korean. To all the the scholars mentioned here I offer my heartfelt thanks.

I take pleasure in acknowledging the debt I owe to the Library of the National Science Foundation and the Burke Branch of the Alexandria Library, which, over the years have enabled me to borrow hundreds of books from libraries all over the United States on inter-library loan. In particular I wish to thank John Moffett, Librarian of the East Asian History of Science Library at the Needham Research Institute, his colleagues Gao Chuan, Tracy Austin and Sally Church, and his predecessors Liang Lien-Chu and Carmen Lee for the time and effort they have expended to locate and copy the materials I needed.

Although I searched for establishments that still practice the art of food processing with traditional equipment during my travels in China in the 1980s and 90s, I was unsuccessful in locating any of them in the cities I visited. The best I could find were factories that follow traditional processing methods but carry them out with modern equipment. These I visited with pleasure and profit. They include:

Shanghai Fermentation Plant No. 6 上海釀造六廠

Soy sauce and soy paste

Shanghai Chinese Wine Fermentation Factory 上海中國釀酒廠

Rice wines, fruit wines, distilled wines

Chiang-nan Beer Factory, Shanghai 江南啤酒廠

Beer, (Brick Ferment), distilled wine

*Tou fu* Production Workshop, at the Fukien Agricultural University, Foochow

*Tou fu* is made fresh everyday

Foochow Winery No. 1 福州第一酒廠

Yellow wine, using the red *ferment*

Foochow Fermentation Plant 福州釀造廠

Soy sauce and soy paste, fish sauce

Ku-thien Red *Ferment* Production Plant 古田紅麴廠

Red *Ferment*, supplied to all manufacturers in Fukien

My thanks go to Wu Te-To for arranging all the visits in Shanghai, to Chen Jiahua for the *tou fu* workshop and Foochow Winery No. 1, and to Chen Jiahua and Rao Pingfan for the Fermentation Plant in Foochow and the Red *ferment* plant in Ku-thien and to the personnel of these facilities who patiently explained to me the details of the processes every step of the way. These visits have enhanced my understanding of how the efficiency of the traditional processes have been increased by the application of modern science and technology. In this connection I wish also to thank Chen Wenhua for organising the memorable trip we took together to Ta-huting, Mi-hsien to see the remarkable Eastern Han wall mural which describes the preparation of *tou fu* in great detail.

When this project began in 1985 I was a Program Director for Biochemistry at the National Science Foundation (NSF), Washington, DC. I spent all the time I could spare on it, in the evenings, on weekends and on holidays, as well as 10 per cent of my official time on weekdays with the blessing of the Foundation. In 1988 I received a six month sabbatical for the project. I wish to take this opportunity to

thank the NSF for the support I enjoyed until my retirement in 1990. Progress should have been much faster after my retirement, but a new obligation intervened. From 1990 to 1994 I served as a part-time Deputy Director of the Needham Research Institute in Cambridge. While it allowed me to take advantage of the facilities of the Library there, it also meant that a great deal of my time was diverted away from the writing of this book, and progress remained slow. It was not until the end of 1995 that a preliminary draft of the whole work was completed. Unfortunately, in early 1996 disaster struck. I had to undergo open heart surgery which effectively incapacitated me for more than four months. But fortunately, my recovery was uneventful and soon I was able to continue with the work. It is, therefore, with a profound sense of joy and relief that I realise the project, which has dominated my life for more than ten years, is at long last drawing to a close.

Those who have kindly read sections of this book in draft form and offered many useful suggestions are:

Anderson, E. N. *Riverside, CA*  
 Aronson, Sheldon *Queens, NY*  
 Bedini, Silvio *Washington, DC*  
 Blue, Gregory *Victoria, BC*  
 Bray, Francesca *Santa Barbara, CA*  
 Chang, K. C. *Cambridge, MA*  
 Cullen, Christopher *Cambridge, UK*  
 Chou, Marilyn *Yorktown, NY*  
 Engelhardt, Ute *München, Germany*  
 Golas, Peter *Denver, CO*  
 Guo Fu *Peking, China*  
 Hong Guangzhu *Peking, China*  
 Hsu, Cho-yun *Pittsburgh, PA and Hong Kong*  
 Huang Shijian *Hangzhou, China*  
 Ishigi, Naomichi *Osaka, Japan*  
 Liu Zuwei *Shanghai, China*  
 McGovern, Patrick *Philadelphia, PA*  
 Métaillé, Georges *Paris, France*  
 Needham, Joseph<sup>23</sup> *Cambridge, UK*  
 Powell, Marvin *DeKalb, IL*  
 Rao, Pingfan *Foochow, China*  
 Robertson, William van *Monterey, CA*  
 Sabban, Françoise *Paris, France*  
 Shurtleff, William *Lafayette, CA*  
 Simoons, Frederick *Spokane, WA*  
 Tsien, Tsuen-Hsuen *Chicago, IL*

<sup>23</sup> Deceased, 24 March 1995.

Ueda, Seinosuke *Kumamoto, Japan*  
Wagner, Donald *Cambridge, UK*  
Wu, Te-To<sup>24</sup> *Shanghai, China*

While their advice and counsel have been invaluable, I alone am responsible for any deficiencies and errors that remain in the text.<sup>25</sup>

Finally, my deepest gratitude goes to the late Joseph Needham, who gave me the inspiration and encouragement to embark on this adventure, and to my wife Rita, whose loving care and constant support have helped to make it come true.

H. T. Huang  
*Alexandria, VA*

<sup>24</sup> Deceased, 29 February 1992.

<sup>25</sup> Unless stated otherwise, all English versions of Chinese passages cited in the text are translated by me; I alone am responsible for any errors in the translations.