Handbook of Milk of Non-Bovine Mammals : camel milk production and utilization

Elsayed I. El-Agamy
Alexandria University Faculty of Agriculture

Handbook of Milk of Non-Bovine Mammals

Edited by
Young W. Park and George F.W. Haenlein

Blackwell
Publishing

Handbook of Milk of Non-Bovine Mammals

Handbook of Milk of Non-Bovine Mammals

Edited by
Young W. Park and George F.W. Haenlein

Blackwell
Publishing

Young W. Park, Ph.D., is professor at the Agricultural Research Station in the College of Agriculture, Home Economics and Allied Programs at Fort Valley State University, Fort Valley, GA, and adjunct professor in the Department of Food Science and Technology, College of Agricultural and Environmental Science at the University of Georgia, Athens, GA.

George F.W. Haenlein, Ph.D., is professor and dairy specialist in the Department of Animal and Food Sciences at the University of Delaware, Newark, DE.

Blackwell Publishing Professional
2121 State Avenue, Ames, Iowa 50014, USA

Orders: 1-800-862-6657
Office: 1-515-292-0140
Fax: 1-515-292-3348
Web site: www.blackwellprofessional.com

Blackwell Publishing Ltd
9600 Garsington Road, Oxford OX4 2DQ, UK
Tel.: +44 (0)1865 776868

Blackwell Publishing Asia
550 Swanston Street, Carlton, Victoria 3053, Australia
Tel.: +61 (0)3 8359 1011

First edition, 2006

Library of Congress Cataloging-in-Publication Data
Handbook of milk of non-bovine mammals / edited by Young W. Park and George F.W. Haenlein.—1st ed.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-8138-2051-4 (alk. paper)
ISBN-10: 0-8138-2051-0 (alk. paper)
1. Milk. 2. Livestock. 3. Dairying. 4. Dairy Products. 5. Nutritional Values. I. Park, Young W. II. Haenlein, George F. W.

SF249.H36 2006
637'.17—dc22

2005013058

The last digit is the print number: 9 8 7 6 5 4 3 2 1

Contents

Contributing Authors

Mary Anne Drake is an Associate Professor in the Department of Food Science, Southeast Dairy Foods Research Center, North Carolina State University, Raleigh, NC, U.S.A. She received her M.S. and Ph.D. degrees in Food Science from Washington State University. She has worked on flavor and flavor chemistry of dairy foods for more than ten years. She is a well-known Sensory Scientist; her research in sensory studies is internationally recognized and she has been invited to deliver paper presentations at numerous national and international symposia. She has published research papers in many refereed journals, book chapters, conference proceedings, and popular articles. She was chosen as an invited outstanding scientist lecturer at the American Dairy Science Association annual conference in 2003. She is an editorial board member for the Journal of Dairy Science and a member of many professional societies including the Institute of Food Technologists (IFT) and the American Dairy Science Association (ADSA).

El-Sayed Ibrahim El-Agamy graduated from the University of Alexandria, Egypt, with a B.S. degree in Dairy Science, an M.S. degree in Dairy Chemistry, and a Ph.D. degree in Immunovirology from Alexandria University and the Institute Armand Frappier, Montreal, Canada. He did research for two years at the Department of Comparative Medicine, Institute Armand Frappier, Montreal. He is Professor of Immunochemistry, Department of Dairy Science, Faculty of Agriculture, Alexandria University. He was awarded the Egyptian national Award for his scientific research. He has served as Director of the Molecular Immunology Laboratory, Center of Biotechnology, Alexandria University. He obtained four research awards from the International Foundation for Science (IFS) in Sweden, TWAS (Italy), and EASR (Egypt and France). He is a member of several national and international societies of dairy science, biochemistry, bacteriology, immunology, animal physiology, biotechnology, and food science in Egypt, Canada, United States, Sweden, France, and England.

Hallvard Gjøstein is a Ph.D. candidate at the Agricultural University of Norway at Ås, Norway. His focus is on lactation physiology and mother-offspring relationships during the lactation period.

Mingruo Guo received a B.S. degree in Animal Science and an M.S. degree in Dairy Technology from Northeast Agricultural University, Harbin, China, and earned a Ph.D. degree in Food Chemistry at the National University of Ireland, Cork, Ireland in 1990. He is an Associate Professor in the Department of Nutrition and Food Sciences, University of Vermont, Burlington, VT. He did postdoctoral research on cheese ripening in the Department of Food Chemistry at the University College Cork for a year and then returned to China for three years to become an Assistant Professor and Associate Professor in the Department of Food Science at the Northeast Agricultural University, Harbin, China. His professional memberships include IFT, ADSA, ACS, and ASCN. He has published more than 100 peer-reviewed journal articles, book chapters, and invited conference proceedings papers, as well as four books.

George F. W. Haenlein is Professor Emeritus of the University of Delaware, Department of Animal and Food Sciences, Newark, DE. He has a Ph.D. degree in

Dairy Science from the University of Wisconsin-Madison, and a D.Sc. degree in Animal Nutrition from the University Hohenheim, Germany, where he also did his undergraduate studies. He emigrated to the United States in 1953, became a naturalized U.S. citizen, and joined the University of Delaware in 1957. He taught courses in dairy production, goat production, behavior of domesticated animals, dairy products judging, genetics of farm animals, and dairy cattle selection. He did research in dairy cattle and dairy goat nutrition, polymorphisms in milk of Guernsey and Holstein cows, and factors affecting milk composition, and he chaired the Sub-Committee of the National Science Foundation on Nutrient Requirements of Goats. He published the Goat Extension Handbook as well as more than 100 research and several hundred extension papers, including topics on goat and sheep milk. He also was Dairy Extension Specialist in charge of Delaware Dairy Herd Improvement (DHIA) programs and worked with many Delaware FFA and 4H dairy products judging teams. He has been active in international dairy improvement programs in 15 foreign countries, especially focusing on small ruminants. He is an editor of the international Small Ruminant Research journal, member of many professional and honorary societies including the American Dairy Science Foundation, the American Dairy Goat Research Foundation, the British Sheep Dairying Association, the American Cheese Society, charter member of the International Goat Association, and honorary fellow of the American Association for the Advancement of Science.

Øystein Holand is an Associate Professor in Reindeer Husbandry at the Agricultural University of Norway, Ås, Norway. His main research field is related to the life history, reproductive biology, and applied population dynamics of ungulates, and semi-domestic reindeer in particular. He received a Ph.D. degree in lactation studies in reindeer with focus on applied lactation physiology and maternal investment during lactation, and he is a recognized leader in that field. His research activities and many publications including refereed journals and conference proceedings on reindeer research are well recognized.

M. Mohamed Habibulla Khan received a B.S. degree in Animal Husbandry, an M.S. degree in Veterinary Science in 1957, and a Ph.D. degree at the Tamil Nadu Agricultural University, Chennai, India. He received post-doctoral training in Dairy Science at Madras Veterinary College, Madras. He has worked in the Department of Animal Husbandry in various capacities including Assistant Research Officer for Buffaloes, and served as Professor and Head of the Department of Dairy Science and Director of Extension Education at the Tamil Nadu Veterinary and Animal Sciences University. He has published more than 50 scientific papers in international and national refereed journals, as well as many popular articles and 11 books on Livestock Production Management. He has served as the Editor of the Cheron Research Journal and Editor of the Kalnadai Kadir Tamil popular journal. He also served as a Task Force Member on Food Biotechnology, Department of Biotechnology, Government of India.

Jane Morgan is an Associate Professor and Reader in Childhood Nutrition at the University of Surrey, Guildford, UK. She holds Ph.D. and R.D. degrees and has a longstanding interest in infant nutrition, which can be traced back to the studies she undertook regarding growth and energy requirements in infancy, and which were the basis for her Ph.D. thesis, published in 1979 at the University of London. She has published widely, has presented papers at national and international conferences, and has been successful in raising funds to support her research. At the University of Surrey she lectures to undergraduate and postgraduate students on all aspects relating to developmental human nutrition.

Mauri Nieminen is Leader of the Reindeer Research Station in Kaamanen, Finland, under the administration of the Finnish Game and Fish Research Institute. His research interest spans from applied physiology and nutrition to range ecology and population dynamics.

Ajit J. Pandya obtained a B.S. degree in Dairy Technology, and M.S. and Ph.D. degrees in Dairy Technology from the National Dairy Research Institute, Karnal, India. He is Professor of Dairy Technology at the Faculty of Dairy Science, Gujarat Agricultural University, Anand, India. He has published many research papers and technical and extension articles. His service established a 100,000-liter-milk-per-day dairy plant for the University.

He was the Organizing Secretary for a National Seminar called "The role of pure ghee in health and nutrition—exploding myths." He is Secretary of the Indian Dairy Association, Gujarat Chapter, Anand, India.

Young W. Park is Professor at the Georgia Small Ruminant Research & Extension Center, Fort Valley State University, Fort Valley, GA, U.S.A., and an Adjunct Professor, Department of Food Science and Technology, University of Georgia, Athens, Georgia. He came to the United States in 1974 after receiving a B.S. degree from Kon Kuk University in Korea. He received an M.S. degree at the University of Minnesota, St. Paul, MN, in 1976, and a Ph.D. degree in Food Chemistry/Nutrition from Utah State University, Logan, Utah in 1981. He also earned a Doctor of Ministry degree at the Northern Baptist Theological Seminary, Chicago, IL, in 1998. He taught courses in food analysis, dairy production, nutrition laboratory, food chemistry, food processing, and dairy products technology. He has devoted his research career to goat milk and dairy goat products research for the past 24 years. He has published more than 180 refereed journal articles, book chapters, and invited papers in symposia and conference proceedings. He is an editorial board member for the Small Ruminant Research journal and has served as a reviewer for many other journals. He is a member of many professional societies, including IFT, ADSA, International Goat Association, American Dairy Goat Association, International Dairy Federation, American Institute of Nutrition, Federation of American Societies for Experimental Biology, and Sigma Xi. He has been invited as symposium speaker and session chair at many international scientific conferences. He also has served as a local church pastor for the past 15 years. He has been nominated to Who's Who in Science and Technology, and 2000 Outstanding Scientists of the 21st Century by the International Biographic Centre, Cambridge, England, and the American Biographic Center, Raleigh, NC, U.S.A.

Moshe Rosenberg received his B.S. degree in Bio-Science, Hebrew University, Jerusalem, Israel, and his M.S. and D.Sc. degrees in Food Engineering and Biotechnology at the Technion Institute of Technology, Haifa, Israel. Since 1990, he has been Professor in the Department of Food Science and Technology at the University of California, Davis, CA. His research is focused on developing the basic understanding and applicable information related to milk-processing technology and engineering, the relationships between the physico-chemical, structural, and rheological properties of dairy foods, and the ultimate quality attributes of the product. His research also investigates the physico-chemical and microencapsulating properties of natural polymers and on developing value-added applications for milk-derived proteins and lipids.

Todd M. Silk received his M.S. and Ph.D. degrees from the University of Vermont, Burlington, VT. As a food microbiologist, his research interests focused on increased detection of *Escherichia coli* O157:H7 in apple cider, and *Listeria monocytogenes* in apple cider and dairy products. Currently, he is involved in research to determine alternative processing strategies for milk and apple cider with minimal heat treatments. Formerly employed at the Northeast Center for Food Entrepreneurship at the University of Vermont, he assisted food entrepreneurs by developing scheduled processes and providing guidance with U.S. Food and Drug Administration regulations. He is currently employed at Wyeth Nutritionals, a U.S. manufacturer of powdered infant formula, and is also an Adjunct Assistant Professor in the Department of Nutrition and Food Sciences at the University of Vermont.

William L. Wendorff graduated from the University of Wisconsin-Madison with a B.S. degree in Dairy Industry, an M.S. degree in Dairy and Food Industries, and a Ph.D. degree in Food Science. After serving 20 years as a technical director in the food industry, he joined the Department of Food Science at the University of Wisconsin-Madison as the Extension Dairy Manufacturing Specialist and Professor of Food Science. He works primarily with the cheese and whey industries. He is the coordinator for the various dairy manufacturing short courses at the University of Wisconsin-Madison and has served as a judge in several national and state cheese contests. Since July 2001, he is serving as Chair of the Food Science Department at UW-Madison. His research activities center on quality and environmental concerns of the dairy industry, and development of sheep milk cheeses. He is a member of ADSA, IAFP, IFT, and the American Cheese Society.

M.E. Carunchia Whetstine graduated from Purdue University in 2000 with a B.S. degree in Food Science. She received her M.S. degree in Food Science in 2002 from North Carolina State University, Raleigh, NC. Currently she is working toward her Ph.D. degree with Dr. Mary Anne Drake as her major professor. Her research is focused on flavor chemistry and sensory analysis, with a special interest in dairy products.

Bolin Zhang has graduated from the Institute of Fermentation Technology & Microbiology, Faculty of Food Chemistry and Biotechnology, Technical University of Lodz, Poland, with a Ph.D. degree in 1997. Presently he is a Professor in the Department of Food Science, School of Biological Science & Technology, Beijing Forestry University, Beijing, China. His major research interest is in food biotechnology and microbiology. He has been involved in research on lactic acid bacteria and related fermentation products, especially fermented dairy products. He and his co-workers have published more than 40 papers in different national or international refereed journals. He is also co-editor of several textbooks and handbooks associated with food biotechnology and food science.

Heping Zhang holds a Ph.D. degree and is Professor at the College of Food Science & Engineering at Inner Mongolia Agricultural University, China, and Chief Engineer at the Dairy Research Center of Inner Mongolia. His research is directed toward immune milk, biological active substances in milk, probiotics, microbiology, and processing technology of koumiss.

Liebing Zhang has a Ph.D. degree, is General Manager of New Hope Dairy, Inc., China, and is Adjunct Professor at the College of Food Science & Engineering at Inner Mongolia Agricultural University. His research interest is focused on the chemistry of milk proteins and processing and technology of cheese and milk powder.

Handbook of Milk of Non-Bovine Mammals

1
Overview of Milk of Non-Bovine Mammals

Young W. Park and George F.W. Haenlein

1 INTRODUCTION

It has been said that many countries are in the midst of a cheese revolution (16). A cheese course may now be part of the final dinner course in many restaurants, and more food stores and markets are offering a great variety of fine domestic and imported *frommage*. This is certainly the situation in Europe and America, and it is especially the case in France. During the last 30 years there has been a reawakening and rediscovery of natural, organic, farm-fresh, artisanal, and original foods for healthier and tastier eating. In this reawakening, dairy goats have also been prominently rediscovered as fitting well the new interest in healthy foods, especially goat milk products, cheeses, and yogurt. Dairy goats have reentered a niche alternative of the dairy industry even in regions in which only dairy cows rule the market. Worldwide FAO statistics also show enormously increasing numbers of goats during recent decades (+61% worldwide from 458 million head in 1980 to 738 million head in 2001) (12, 13) (see Chapter 2, Table 2.3). Dairy cows and their products have been synonymous with the concept of the dairy industry in much of the developed world, in market places and textbooks for a long time. More than 95% of dairy products have been derived from cow milk, except in countries of the Mediterranean basin. Students of dairy science learned mostly only of cows producing milk products. Archeological findings from ancient Mesopotamia, Egypt, and India show the milking mainly of cows and the making of butter and cheese (31). Even U.S. regulatory agencies and State Board of Health authorities had as their ruling dairy code the definition of milk "as being derived from cows" until recently.

This situation changed about 30 years ago, especially in America, and continues to change. Now, dairy goats have finally become accepted as a legitimate addition to the dairy industry by U.S. state regulatory authorities. Furthermore, during the last 10 years, dairy sheep have also entered America and have fast become a new and acceptable part of the dairy industry. What is a strong tradition in many Mediterranean countries and other parts of the world has finally arrived in America. Increased importation of dairy products from goat and sheep milk, even buffalo milk, from other countries to satisfy a growing interest of consumers is integrating with new domestic production from dairy goats and dairy sheep. In other parts of the world, more than just goats and sheep are important or even the principal milk producers because of steep mountains, deserts and harsh climate, poverty, economics, and long tradition. Other mammalian species besides cows are also very significant milk providers, such as camels, yaks, buffaloes, mares, reindeer, even llamas, and their contributions must not be overlooked in dairy science teaching. America has even now one or two dairy buffalo herds, and one or two commercial dairy mare herds exist in Europe and America besides the many in Asia.

Today's consumers in developing and developed countries are also more and more sophisticated in their desire to know about the composition and constituents in dairy products as they relate to human health (9, 34). Hardly anybody paid much attention or knew much about good and bad types of fat and fatty acids until recently. Today's nutrition labels on food products indicate levels not only of protein, fat, carbohydrates, sodium, calcium, and vitamins but also of such special ingredients as saturated, unsaturated, omega-3, conjugated, and trans-fatty acids. This open knowledge leads to interest into ascertaining which dairy products may be superior to others, and which animal feeding system is best, such as pasturing versus barn feeding, and which animal species produces a more suitable or preferable human food to others. In terms of milk for infants or sick patients, answers are sought as to which milk is closest to human milk and best for babies, or which milk creates fewer allergies, which one is better tolerated by people with gastrointestinal ailments, and which dairy product causes no lactose intolerance symptoms.

2 MAMMALS IN THE ANIMAL KINGDOM

The natural law of survival in the animal kingdom is founded upon the preservation of its offspring. The highest class of animals evolved with mammary glands for the nourishment of their young after birth are called *Mammalia* (33). The fetus developing in the placenta of most mammals is born in a more or less helpless state. Upon birth, the young are nursed by their mothers with milk, which is a physiologically and nutritionally balanced secretion of the mammary gland.

The mammary glands of cows, sheep, goats, deer, camel, horses, and even whales are located in the inguinal region; those of primates and elephants are in the thoracic region, but those of pigs, rodents, and carnivores are along the ventral surface of the thorax and abdomen (37). The mammary gland, as with sebaceous and sweat glands, is a cutaneous gland. Milk is formed by synthesis and diffusion processes from the blood in the mammary gland. This lactogenesis occurs concomitantly with parturition in most mammals, although there are small quantities of precolostrum formed in the mammary gland in later stages of pregnancy (26).

Milk has been described as the most perfect food in nature. Milk is balanced for most nutrients and often has a high caloric value. It can meet the nutritional requirements of the newborn during its early critical period of body development, and provides essential nutrition for normal growth, until the newborn is able to consume and digest solid foods. All mammalian young are completely dependent on mother's milk until they begin to feed on their own and are weaned weeks after parturition.

3 EVOLUTION OF THE DAIRY INDUSTRY

In search of socioeconomically feasible and nutritionally superior sources of foods, humanity has domesticated some mammalian species and selected and bred them to produce large volumes of milk in excess of the necessary amounts to nourish the animal's own offspring. This surplus of milk production beyond nourishing the young has become the foundation of the modern dairy industry. In North America, Europe, Australia, and New Zealand, the dairy industry is one of the most integral enterprises among all agricultural production businesses.

Although the dairy cow has been the predominant domesticated animal species for dairy production in developed countries, the goat, sheep, water buffalo, yak, camel, and mare as well as some other minor mammalian species have been domesticated, kept, and bred for milk production in regions of the world where the difficult environment required special adaptation and for which many of the nonbovine mammals are better suited.

Understanding the anatomy, histology, physiology, and biochemistry of milk component synthesis and its secretory processes in the mammary gland is important for production, maintenance, and utilization of milk for human consumption. Greater knowledge of this will provide dairy producers with the essential capacity to improve management and environmental conditions of their dairy animals for higher efficiency, greater quality, and larger volumes of milk production. Such knowledge also would give dairy producers opportunities for affecting the composition of milk to meet more functionally the nutrition and health needs of people.

Milk is one of the most precious natural foods and has been a basic component of the human diet since early history. Milk drawn from the lacteal glands is highly perishable and adversely affected by improper practices of feeding and handling of the animals, handling of milk during and after milking, cooling, transportation, pasteurization, processing, packaging, processing equipment, and storage (22, 30). Through understanding of the basic science of lactation in domesticated mammals, the milk production volume and quality can be maximized for effective utilization and processing of milk products for human consumption.

4 COMPOSITION AND SECRETION OF MILK OF MINOR SPECIES

In a comprehensive review of milk of mammalian species, Oftedal (27) was able to locate compositional data for at least 194 species. However, there were relatively few careful studies on nondomestic species. Only 55 species, including domesticated mammals, had systematic data for all lactation stages. It was shown that much of the available information, especially on wild species, was from opportunistic situations, in which effects of stage of lactation, compromised maternal or infant health, and sampling bias could not be tested (28).

Milk constituents are produced either directly or indirectly from blood. Even if the osmotic pressure is the same for milk and blood, markedly different compositions exist between the two physiological body fluids. Milk proteins are mainly caseins, at least in ruminants, while the principal proteins in blood plasma are albumins and globulins. In addition, milk contains more sugar (lactose), fat (lipids), calcium, phosphorus, and potassium, but often less protein, sodium, and chlorine than blood (37).

Milk contains two characteristic components, lactose and casein, besides fat, minerals, and vitamins. Even though the composition of milk is influenced by genetic, nutritional, and environmental factors, the amounts of the major and minor constituents in milk vary genetically substantially between species. In general, milk of marine mammals such as dolphins, seals, whales, and polar bears contains a high fat content (37). Many of the rapidly growing species, such as the rabbit and rat, have high protein contents in their milk, but the correlated relationships between rates of reaching maturity and levels of protein in milk are not consistently linear. The most constant component in milk is lactose, which is found in between 3 and 7% in mid-lactation milk of different species. Among marsupials, a class just below mammals but also providing milk to their young inside their pouch, the kangaroo milk contains pentoses instead of lactose, as well as proteins and other nitrogenous compounds, which are not usually associated with mammalian milk (7).

Milk composition of domesticated and some wild mammals is shown in Table 1.1. These values are average figures and can be used only for general comparisons between species.

Many data in the table, especially for nondomesticated species, are based on few analyses and have little information about the stage of lactation, when the milk samples were taken. There can even be significant differences in composition of milk between different glands of the same animal, and substantial variations do occur diurnally and from day to day.

Lactogenesis or the onset of copious milk secretion occurs concomitantly with parturition in most mammalian species. Lactogenesis takes place in two stages (14, 19). The first prepares the mammary glands for milk secretion, and this usually occurs sometime in later pregnancy. The second stage is the onset of milk secretion at the time of parturition.

In the cow, lactogenesis coincides with parturition (29). In the rat, milk is secreted into the mammary ducts four hours prior to parturition (21). On the other hand, lactogenesis is delayed for 48 or 72 hours postpartum in humans and guinea pigs, which may be attributable to the slow postpartum decrease in progesterone levels in the two species (25).

Hormones have definite influences on the initiation of the milk secretion process. The continued secretion, the amount of milk produced, and the composition of milk are controlled by several hormonal and nutritional factors within the animal. In dairy cows and goats, somatotrophin and thyroxine increase the level of milk production (33, 37) and have to be removed periodically in order for secretion of milk to continue. However, secretion of milk, that is, its removal, from the mammary gland usually requires the stimulation of the nervous system through the young's suckling or manual premilking procedures. If the milk is not evacuated from the glands, the secretory process declines and secretion stops with a complete involution of the secretory tissues. Milk secretion proceeds by a physiological feedback system. The nervous stimulus induces the release through the bloodstream of the hormone oxytocin from the pituitary gland in the brain, which causes the myoepithelial cells surrounding the milk-producing alveoli to contract, thus forcing the milk from the alveoli into the udder ducts and cisterns (33).

Table 1.1. Gross Composition (%) of Milk from Domesticated and Some Wild Mammals

Species	Fat	Protein	Lactose	Ash	Total solids	Reference
Antelope						
Impala	20.4	10.8	2.4	1.3	34.9	5
Pronghorn	13.0	6.9	4.0	1.3	25.2	10
Ass (donkey)	1.2	1.7	6.9	0.4	10.2	35
Baboon	5.0	1.6	7.3	0.3	14.2	8
Bear						
Grizzly	3.0	3.8	4.0	1.3	12.1	5
Polar	31.0	10.2	0.5	1.2	42.9	4
Bison	1.7	4.8	5.7	0.9	13.1	1
Buffalo						
Egyptian	7.7	4.3	4.7	0.8	17.5	1
Philippine	10.4	5.9	4.3	0.8	21.4	1
Camel	4.9	3.7	5.1	0.7	14.4	35
Cat	7.1	10.1	4.2	0.5	21.9	1
Cow						
Ayrshire	4.1	3.6	4.7	0.7	13.1	3
Brown Swiss	4.0	3.6	5.0	0.7	13.3	3
Guernsey	5.0	3.8	4.9	0.7	14.4	3
Holstein	3.5	3.1	4.9	0.7	12.2	3
Jersey	5.5	3.9	4.9	0.7	15.0	3
Zebu	4.9	3.9	5.1	0.8	14.7	38
Chimpanzee	3.7	1.2	7.0	0.2	12.1	5
Coyote	10.7	9.9	3.0	0.9	24.5	5
Deer	19.7	10.4	2.6	1.4	34.1	36
Dog	8.3	9.5	3.7	1.2	20.7	35
Dolphin	41.5	10.9	1.1	0.7	54.2	1
Elephant	15.1	4.2	5.1	0.7	24.1	1
Fox	6.3	6.3	4.7	1.0	18.3	39
Goat	3.5	3.1	4.6	0.8	12.1	35
Guinea pig	3.9	8.1	3.0	0.8	15.8	35
Horse	1.6	2.7	6.1	0.5	11.0	35
Human	4.5	1.1	6.8	0.2	12.6	15
(Kangaroo)[1]	2.1	6.2	trace	1.2	9.5	7
Mink	8.0	7.0	6.9	0.7	22.6	20
Monkey	3.9	2.1	5.9	0.3	12.3	35
Moose	7.0	13.5	3.6	1.6	25.7	5
Mouse	12.1	9.0	3.2	1.5	25.8	5
Mule	1.8	2.0	5.5	0.5	9.8	1
Musk ox	11.0	5.3	3.6	1.8	21.7	11
Opossum	6.1	9.2	3.2	1.6	24.5	17
Rabbit	12.2	10.4	1.8	2.0	26.4	6
Rat	14.8	11.3	2.9	1.5	31.8	1
Reindeer	22.5	10.3	2.5	1.4	36.7	1
Sea lion, CA[2]	34.9	13.6	0.0	0.6	49.1	32
Seal						
Gray	53.2	11.2	2.6	0.7	67.7	2
Hooded	40.4	6.6	?	0.9	47.9	5
Sheep	5.3	5.5	4.6	0.9	16.3	35
Swine	7.9	5.9	4.9	0.9	19.6	24
Whale	34.8	13.6	1.8	1.6	51.2	1
Yak	7.0	5.2	4.6	?	16.8	23
Zebra	4.8	3.0	5.3	0.7	13.8	1

[1]Marsupial. [2]CA = California.

5 UNIQUENESS OF THIS BOOK ON MILK OF NON-BOVINE MAMMALS

The technical and popular literature abounds with publications about the world of cow milk, while milk of other mammals has garnered little attention, at least in the English language. Therefore it was the fervent interest of Dr. Y.W. Park and Dr. G.F.W. Haenlein in producing this book to make a comprehensive and new contribution to the dairy science of the non-bovine mammals, and to overcome to some extent the paucity of published knowledge by bringing in contributions from noted scientists in foreign countries, where non-bovine mammals have an important nutritional, economic, and social role.

This book presents chapters about the production and utilization of 10 non-bovine mammals: goats, sheep, buffaloes, mares, camels, yaks, reindeer, sows, llamas, and humans. Focus on dairy goats was the initial motivator for the book, because of some unique characteristics of goat milk compared to cow milk. Goat milk has been used successfully in cases of cow milk allergies and by patients with various metabolic and gastrointestinal ailments. Goat milk proteins can differ genetically from some cow milk proteins, and goat milk fat has usually a better profile of fatty acids. Goat milk cheeses have acquired a worldwide gourmet reputation, and demand is growing.

Sheep have been milked for millenia, but mainly as part of triple-purpose breeding for fiber and meat production besides milk. Therefore official statistical records of dairy sheep populations, and sheep milk production and processing, are hard to find. Sheep milk has unique composition and is ideally suited for yogurt and cheese production (18). Sheep cheese production is well organized and promoted in some countries and in exports, where sheep cheeses are highly regarded, especially because of some official protection of origin label.

Buffalo milk is important in Asian countries mainly, but the distribution of buffalo populations and interest in buffalo milk products is spreading. India has supported officially significant research with dairy buffaloes, including at a national research institute (CIRB) specifically devoted to buffaloes at Hisar–Haryana, and the comprehensive contributions by Dr. A.J. Pandya and Dr. M.M.H. Khan to this book are particularly valuable. Buffalo milk is popular in many traditional products, which are not well known in Western countries.

Mare milk is another Asian uniqueness, with much tradition in some countries, but also with some good justification as an alternative to cow milk and treatment for humans with debilities. Research with mare milk and appreciation of its qualities is limited in the West except for a few proponents, partly because of the language barrier.

Camel milk also has unique compositional differences from cow milk, among which is an absence of beta-lactoglobulin, which makes it more similar to human milk. Dr. El-Agamy's research and comprehensive contribution to this book, especially concerning milk protein allergies, biological activities of the protective proteins in milk, lysozyme, lactoferrin, lactoperoxidase, and antiviral activities are particularly valuable.

The yak is a valuable milk-producing animal in a few Asian countries with very harsh climates, but has undeservedly received little research attention and appreciation in the West. Uniquely, yak milk is dried in several factories near yak-rearing areas in China, Nepal, and possibly also in Mongolia for popular domestic consumption. Yak butter is an important staple food from yak milk besides several types of yogurt and cheeses.

Reindeer milk has received new interest from researchers in the North, mainly because of its highest level of milk composition among the discussed mammals in this book and the unique adaptation of this ruminant mammal to the very harsh climate. Protein in reindeer milk is about three times the level in cow milk (11% verssus 3%), but lactose is uniquely less (3.5% versus 4.5%). Yet, the economics of reindeer milk production and herding management need much attention.

Sow milk is of considerable academic and research interest because of the physiological similarity of this monogastric to human milk secretion. Nutritional, physiological, and biochemical research data on sow milk can be effectively utilized and applied to related situations in human metabolism, health, and medicine. Sow milk production is also of considerable husbandry interest, because high piglet mortality and limited growth of piglets is linked to low sow milk production.

Llamas are, like camels, regurgitating herbivores, but have only three stomachs instead of the four of the true ruminants. Llamas, or any of the other three South American camelids, Alpaca, Vicuña, and Guanaco, have not been bred or used for commercial milk production, which presents a very unique historic situation for native South Americans before the arrival of European dairy animals. The question of from where those native people obtained their necessary supplies of calcium in the absence of any milk products in their adult diet has not been answered satisfactorily. Academic interest in llama milk has been related to the need to develop satisfactory milk replacer formulae for raising newborn llamas.

Additional other minor species milks that are not included as a major chapter are discussed for a more rounded presentation in this book. Academically, there should be much stimulation from the different uniquenesses among those species.

Finally, knowledge in human milk is needed much more widely because of its superior value in infant nutrition, satisfactory health, and growth, compared to most other animal or vegetable formula substitutes. Processing of human milk is also of increasing interest as a commercial source for mothers in need of such supplementation.

No one can deny the fact that cows are the primary dairy animal species in many countries to provide humans with nutritious food through the abundance of their lacteal secretion. Goats and other minor dairy species will never be able to compete with cows in terms of volume of milk production. However, the contribution of milk from other domesticated dairy species to the survival and well being of people around the world is immense and invaluable, especially in areas where cows have difficulty surviving.

Nevertheless, the traditional dairy-cow-dominated dairy industry is and will become more diversified in domestic productions, and it is already in the market place on shelves of many food stores, where a great variety of domestic and imported dairy products from dairy goats, dairy sheep, even “mozzarella di buffalo,” are now available with high quality. Consumers of such new products found in grocery stores and on restaurant menus are increasingly interested in the histories, origins, and comparative values of these diverse products from species other than dairy cows.

This book is intended to fit this evolution in the dairy market place. There has not been a book, as far as we know, covering the origin, production, composition, processing, and uniqueness of milk and its products from other domesticated mammals besides the dairy cow. This book provides comprehensive reviews of what is known in other parts of the world by dairy scientists with special knowledge in the areas of non-bovine milk. This book is intended for students in agriculture, veterinary science, even economics and political science, but in particular dairy science, to bridge the gap that has existed far too long. And this book is also aimed at the consumers who like to widen their horizon and knowledge about what they are eating, or what else might be great or beneficial to eat, and where it comes from. This book is not only for people in the developing world who want and need to better their food supply quantitatively and qualitatively, but is especially for people in the developed world who may have medical needs for alternative foods and treatment, or for gourmet-connoisseur consumers looking for a higher-quality menu.

REFERENCES

1. Altman, P.L., and D.S. Dittmer (eds.). 1961. Blood and other body fluids. Fed. Am.Soc. Exp. Biol. Washington, D.C.
2. Amoroso, E.C., A. Goffin, G. Halley, L.H. Matthews, and D.J. Matthews.1951. Lactation in the grey seal. J. Physiol. 113:4P–5P.
3. Armstrong, T.V. 1959. Variations in the gross composition of milk as related to the breed of cow: A review and critical evaluation of literature of the United States and Canada. J. Dairy Sci. 42:1–19.
4. Baker, B.E., C.R. Harrington, and A.L. Symes. 1963. Polar bear milk. I. Gross composition and fat constitution. Can. J. Zool. 41:1035–1039.
5. Ben Shaul, D.M. 1962. The composition of milk of wild animals. Internat. Zoo Yearbook. 4:333–342.
6. Bergman, A.J., and C.W. Turner. 1937. The composition of rabbit milk stimulated by the lactogenic hormones. J. Biol. Chem. 120:21–27.
7. Bolliger, A., and J.V. Pascoe. 1953. Composition of Kangaroo milk (Wallaroo, *Macropus robustus)*. Austr. J. Sci. 15:215–217.
8. Buss, D.H. 1968. Gross composition and variation of the components of Baboon milk during natural lactation. J. Nutr. 96:421–426.
9. Campbell, J.R., and R.T. Marshall. 1975. The Science of Providing Milk for Man. McGraw-Hill Book Co., 801 p.
10. Einarsen, A.S. 1948. The Pronghorn Antelope, and Its Management. Wildlife Management Institute. Washington, D.C.
11. Evans, D.E. 1959. Milk composition of mammals whose milk is not normally used for human consumption. Dairy Sci. Abstr. 21:277–288.
12. FAO. 1986. Production Yearbook, FAO, Rome, 320 p.
13. FAO. 2002. Production Yearbook, FAO, Rome, 261 p.
14. Fleet, I.R., J.A. Goode, M.H. Harmon, M.S. Laurie, J.L. Linzell, and M. Peaker. 1975. Secretory activity of goat mammary glands during pregnancy and the onset of lactation. J. Physiol. 251:763–773.

15. Fomon, S.J., D.H. Clement, G.B Forbes, D. Fraser, A.E. Hansen, C.U. Lowe, C.D. May, C.A. Smith, and N.J. Smith. 1960. Composition of milks. Pediatrics, 26:1039–1049.

16. Garvey, H. 2004. Bringing the cheese course home. Bon Appétit magazine, Jan.:21.

17. Gross, R., and A. Bolliger. 1959. Composition of milk of the marsupial *Trichosurus vulpecula.* Am. J. Dis. Child. 98: 768–775.

18. Haenlein, G.F.W. 1996. Nutritional value of dairy products of ewe and goat milk. Pages 159–178 in Proceedings, IDF-CIRVAL Seminar Production and Utilization of Ewe and Goat milk, Crete, Greece, Oct. 19–21, 1995. International Dairy Federation Publ., Brussels, Belgium.

19. Hartmann, P.E. 1973. Changes in the composition and yield of the mammary secretion of cows during the initiation of lactation. J. Endocrinol. 59:213–247.

20. Jorgensen, G. 1960. Composition and nutritive value of mink's milk. Nutr. Abstr. Rev., 30:1218.

21. Kuhn, N.J. 1977. Lactogenesis: The search for trigger mechanisms in different species. In: Comparative Aspects of Lactation. M. Peaker (ed.), p. 165–172. Academic Press, London.

22. LeJaouen, J.C. 1987. The Fabrication of Farmstead Goat Cheese. p. 45–121. Cheesemaker's Journal, Ashfield, MA.

23. Ling, E.R., S.K. Kon, and J.W.G. Porter. 1961. The composition of milk and the nutritive value of its components. In: Milk: The Mammary Gland and its Secretion, S.K. Kon and A.T. Cowie (eds.). Academic Press, New York. Vol. 2.

24. Lodge, G.A. 1959. The composition of sow's milk during lactation with particular reference to the relationship between protein and lactose. J. Dairy Res. 26:134–139.

25. Neville, M.C. 1983. Regulation of mammary development and lactation. In: Lactation, Physiology, Nutrition and Breast-feeding, M.C. Neville and M.R. Neifert (eds.), p. 103–140. Plenum Press, New York.

26. Neville, M.C. 1995. Determinants of milk volume and composition. In: Handbook of Milk Composition, R.G. Jensen (ed.). Academic Press, San Diego, p 87–98.

27. Oftedal, O.T. 1984. Milk composition, milk yield and energy output at peak lactation. A comparative review. Symp. Zool. Soc. London. 51:33–85.

28. Oftedal O.T., and S.J. Iverson. 1995. Comparative analysis of non-human milks. In: Handbook of Milk Composition. R.G. Jensen (ed.). Academic Press, San Diego, New York, London, p 749–788.

29. Peaker, M., and J.L. Linzell. 1975. Citrate in milk: Harbinger of lactogenesis. Nature 253:464–465.

30. Peters, R.R. 1990. Proper milk handling. Dairy Goat J. 68 (4):223–227.

31. Petersen, W.E. 1950. Dairy Science. J.B. Lippincott Co., Chicago, 695 p.

32. Pilson, M.E.Q., and A.L. Kelley. 1962. Composition of the milk from *Zalophus californianus,* the California sea lion. Science 135:104–105.

33. Schmidt, G.H. 1971. Biology of Lactation. W.H. Freeman Co., San Francisco, 635 p.

34. Smith, A.J. (ed.). 1985. Milk Production in Developing Countries. Proceedings Conference Edinburgh Centre Tropical Veterinary Medicine, April 2–6, 1984, University Edinburgh Publ., Edinburgh, U.K., 555 p.

35. Smith, V.R. 1959. Physiology of Lactation. 5th ed. Iowa State University Press. Ames, Iowa.

36. Spector, W.S. 1956. Handbook of Biological Data. W.S. Spector (ed.). W.B. Saunders, Philadelphia.

37. Swenson, M.J. 1975. Duke's Physiology of Domestic Animals. 8th ed. M.J. Swenson (ed.). Cornell University Press, Ithaca, London, p. 1366–1383.

38. Verdiev, Z., and D. Veli-Zade. 1960. Physico-chemical properties of milk of Azerbaijan Zebu cattle. Dairy Sci. Abstr. 22:471.

39. Young, E.G., and G.A. Grant. 1931. The composition of vixen milk. J. Biol. Chem. 93:805–810.

2
Goat Milk

2.1 Production of Goat Milk

George F.W. Haenlein

1 INTRODUCTION

The goat has been the most maligned domesticated animal and still is in many parts of the world (90), partly because of its sometimes offensive odor, especially from the buck, whose odor floats strongly around the premises and can affect the flavor of the doe's milk, if ventilation, milking practices, and cooling of the milk are improper or insufficient. For the doe this odor is an aphrodisiac enticing her libido and is part of the "buck effect" to stimulate sexual activity (65, 78). In recent years it has been convincingly demonstrated that properly milked and cooled goat milk is odor free and hard to distinguish from cow milk in odor and taste (8, 71). Thus, quality goat milk production is possible and has made great progress in recent years in dismantling the age-old prejudice by consumers. This may in part also be reflected in the phenomenal increase in dairy goat numbers around the world in recent years (Tables 2.3–2.5). Another severe prejudice has long existed among forestry officials' claim that goats are responsible for de-forestation and desertification because of their feeding preference in browsing bushes, twigs, barks, and even climbing tree limbs (13, 24, 71, 101) (Figure 2.1). However, it has been demonstrated that human management practices of overstocking and free grazing without a shepherd are to blame, and that responsible feeding of harvested tree leaves and pods is a more environmentally friendly alternative, especially since goats tolerate tannin and phenolic compounds in leaves, whereas cattle, sheep, and horses do not (74, 98, 100). In addition, goats in many parts of the world are successfully used in "integrated grazing" with cattle and sheep to clear pastures from brush and tree encroachment, thus saving and improving beef and sheep pasture grazing for higher performance per unit of land area, and also providing better protection from predators (47). In areas with traditional migratory or transhumance grazing, the herds were always a mixture of goats, sheep, and some cattle and donkeys. Goats are also used to provide brush and forest clearance for wildfire control (3, 45).

Milk production annual tonnage from goats is a relatively small amount compared to cow and buffalo milk production worldwide (Table 2.1), but it has increased in Africa, Europe, and worldwide percentage-wise. In actual milk tonnage the increases are very significant (Table 2.2), except for Central America (Table 2.5). This tonnage increase better reflects the great importance of goat milk around the world, especially when held next to the large increases of goat population numbers (Table 2.3). It also explains the conviction by dairy experts that more goat milk is consumed by more people around the world than any other milk (24), and that goat milk is a main food to sustain poor people and small farmers, to prevent mal- and undernutrition, and to aid people with cow milk allergies (38, 59, 77, 79). Foreign aid

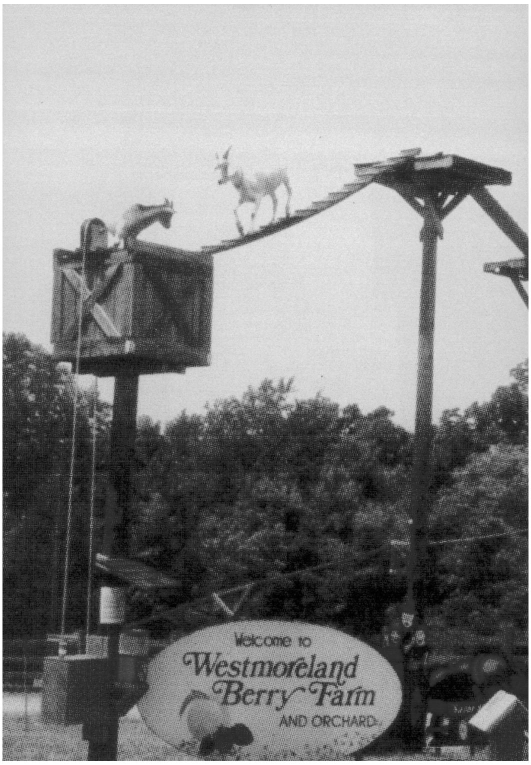

Figure 2.1. Sure-footed, fearless goats are climbing an 8 m-high board-trail to a feeding station, illustrating the ability of goats to climb tree limbs to feed on leaves. Here at the Westmoreland Berry Farm, Virginia, U.S.A., the goats attract visitors, who have fun feeding the goats small amounts of corn kernels hoisted up in a small bucket to the feeding station above. Photo Westmoreland Berry Farm, Oakgrove, VA; by permission.

Table 2.1. Milk Production by Species Relative to All Milk Produced within Continent and Trends during the Last 20 Years (20, 21)

Year	1980	2001
All milk[1]	100.0 %	100.0 %
SHEEP[2]		
World	1.7	1.3
Africa	7.0	6.6
S. America	0.1	0.07
Asia	5.1	1.9
Europe	1.9	1.3
GOATS[3]		
World	1.6	2.1
Africa	10.4	11.0
N. C. America	0.4	0.2
S. America	0.6	0.4
Asia	5.2	4.0
Europe	1.0	1.1
BUFFALOES[4]		
World	5.9	11.9
Africa	8.8	8.2
Asia	39.6	38.5
Europe	0.1	0.1
COWS		
World	90.8	84.6
Africa	73.8	74.2
N. C. America	99.6	99.8
S. America	99.3	99.5
Asia	50.1	55.6
Europe	97.2	97.5
Oceania	100.0	100.0

[1]Includes milk of cows, buffaloes, goats, and sheep.
[2]North and Central America and Oceania; no data.
[3]Oceania; no data.
[4]Americas and Oceania; no data.

project leaders in developing countries have long recognized this and focused their efforts on improving dairy goat breeding, nutrition, and milk yields (42). Within continents, Africa leads in goat milk production relative to all milk produced there (Table 2.1), but Asia leads in total annual milk tonnage, in total goat numbers, and in relative increase of goat milk production during the last 20 years (Tables 2.2–2.3). FAO data do not distinguish between dairy, cashmere, and Angora goats. The latter are of significant numbers in some Asian countries, South Africa, Turkey and Texas,U.S.A. (Table 2.5), but data of milk production tonnage help identify countries with dairy goat populations. Table 2.2 also shows that during the last 20 years the total world tonnage of goat milk has increased much beyond that of sheep milk production (12.4 million MT vs. 7.8 million MT, respectively, in 2001), but this difference probably reflects also the increased demand for fluid milk consumption, whereas sheep milk is mainly processed into cheeses. Worldwide, the numbers of people increased by 38% during the last 20 years, but goat milk production increased by 72% (Tables 2.2–2.3).

Table 2.2. Total Milk Production by Species during the Last 20 Years and Relative Proportion for Each Continent within Species (20, 21)

Year	1980 1,000 MT	2001 1,000 MT	Change, % 2001–1980	World, % 1980	World, % 2001
GOATS[1]					
World	7,236	12,455	+72	100	100
Africa	1,477	2,773	+88	20	22
N. C. America	318	165	−48	4	1
S. America	134	182	+36	2	1
Asia	3,435	7,017	+104	48	56
Europe	1,569	2,317	+48	22	19
SHEEP[2]					
World	7,980	7,808	−2	100	100
Africa	994	1,648	+66	12	21
S. America	34	35	+3	0.4	0.4
Asia	3,396	3,269	−4	42	42
Europe	3,482	2,856	−18	44	37
Mediterranean	4,289	4,523	+5	54	58
BUFFALOES[3]					
World	27,491	69,248	+152	100	100
Africa	1,248	2,051	+164	4	3
Asia	26,148	67,028	+156	95	97
Europe	96	170	+77	0.3	0.2
COWS					
World	423,034	493,828	+17	100	100
Africa	10,477	18,645	+78	2	4
N. C. America	76,540	96,638	+26	18	20
S. America	23,935	47,055	+97	6	10
Asia	33,084	96,674	+192	8	20
Europe	176,200	210,193	+19	42	43
Oceania	12,240	24,623	+101	3	5
ALL MILK					
World	465,741	583,339	+25	100	100
Africa	14,196	25,117	+77	3	4
N. C. America	76,858	96,803	+26	16	17
S. America	24,103	47,272	+96	5	8
Asia	66,063	173,988	+163	14	30
Europe	181,347	215,536	+19	39	37
Oceania	12,240	24,623	+101	3	4

[1]Oceania; no data.
[2]N. and C. America and Oceania; no data.
[3]Americas and Oceania; no data.

The Mediterranean region with some 21 countries is the major sheep milk production area of the world (Table 2.2), but not so for goat milk production, which amounted to 34% of all goat milk tonnage worldwide in 1980 but only 18% in 2001 for that region (Table 2.4). In total tonnage, Asia and Africa produced much more goat milk than did the Mediterranean region in 2001. North America does not have any FAO goat milk data listed, and Europe has more countries decreasing than increasing in

Table 2.3. Trends of Populations of Goats and People during the Last 20 Years (20, 21)

	1980	2001	Change,% 2001–1980
GOATS (Million head)			
World	458	738	+61
Africa	149	219	+47
N. C. America	13	14	+8
S. America	19	22	+16
Asia	258	465	+80
Europe	12	18	+50
Mediterranean region	44	40	−9
Oceania	0.4	0.7	+75
PEOPLE (Million head)			
World	4,450	6,134	+38
Africa	480	812	+69
N. C. America	373	493	+32
S. America	240	351	+46
Asia	2,584	3,721	+44
Europe	484	726	+50
Oceania	23	31	+35

goat milk tonnage per year (Tables 2.4 and 2.5). Thus, a general and historic disinterest in goat milk research, relative to cow milk and sheep research, in these countries may be understandable, though not forgivable, and the world literature on goat milk production, product technology, and marketing has to depend on such research from Asia and Africa.

2 MILK PRODUCTION

2.1 Breeds of Goats

The goat is one of the most versatile domestic animals in adaptation to arid and humid, tropical and cold, and desert and mountain conditions (29, 81, 97), providing people with many important products: meat, milk including yogurt and cheese, cashmere, mohair, skins, draft and pack power, and manure for crops and gardens (28, 43). Shkolnik et al. (96) studied the adaptation of the small Bedouin goat, weighing between 15 to 25 kg, to arid desert conditions. By providing watering opportunities only every two to four days, the goat's foraging range was increased greatly. Goats lost body weight during water deprivation but maintained daily milk yields of up to 2 kg nevertheless. Mason (61) lists 411 goat breeds in his world dictionary of livestock, but only about 31 as primary dairy breeds (Table 2.6). Gall (30) provides detailed description and production data of 160 goat breeds based on size of populations, productivity, and unique characteristics. Levels of milk production from surveys in 46 countries around the world are given for 89 goat breeds. Among these are four recognized as high-yielding breeds—Alpine, Saanen, Toggenburg, and Nubian—which are also called "improver" breeds for developing countries (14). The Swiss breeds, Saanen in particular, have been exported and adapted in many countries, forming new local breeds, often with new names (60). Compared to dairy sheep, genetic selection of dairy goats has succeeded in much higher milk yields, longer lactation length (Table 2.7), and better udder conformation, especially among the Swiss breeds. Milk yield production data vary much from country to country for the same breed, depending on feeding, climate, and disease adaptation. Milk composition varies between breeds but is generally lower (3.3–4.7% fat, 2.9–5.0% protein, 4.1–5.2% lactose, 11.5–15.1% total solids) than for dairy sheep, except for West African Dwarf

Table 2.4. Mediterranean Region Goat Populations, Goat Milk Production, and Trends during the Last 20 years (20, 21)

	GOAT POPULATIONS			GOAT MILK PRODUCTION		
	1980 1,000 head	2001 1,000 head	Change, % 2001–1980	1980 1,000 MT	2001 1,000 MT	Change, % 2001–1980
Portugal	747	760	+2	37	35	−6
Spain	2,120	2,830	+33	302	320	+6
France	1,065	1,200	+13	464	460	−1
Italy	989	1,375	+39	118	140	+19
Malta	6	9	+50	2	-	-
Cyprus	360	379	+5	37	29	−22
Yugoslavia 125	343	+ 174	-	-	-	
Albania	672	1,120	+67	27	80	+196
Hungary	120	150	+25	4	10	+150
Romania	378	574	+52	-	-	
Bulgaria	425	970	+128	60	215	+258
Greece	4,555	5,300	+16	425	450	+6
Turkey	18,755	8,057	−57	623	225	−64
Lebanon	413	445	+8	35	39	+11
Israel	132	68	−48	24	13	−46
Syria	1,028	979	−5	74	62	−16
Egypt	1,451	3,527	+143	8	15	+88
Tunisia	822	1,450	+76	13	12	−-8
Libya	1,400	1,950	+39	15	15	±$0
Algeria	2,763	3,500	+27	134	155	+16
Morocco	5,773	5,200	−10	27	35	+30
21 Total	44,099	40,186	−9	2,429	2,310	−6
World	457,660	738,246	+61	7,236	12,455	+72
21 Mediterranean, % of world	10	5	34	18		

goats, which may have much higher fat (7.8%), protein (5.3%), lactose (5.2%), and total solids (18.8%) contents (14, 64).

Breeds that are managed in registry herd books combined with milk recording and sire-proving schemes are generally the leaders (35, 39). Thus, individual record performances of Spanish Canaria, Malagueña, and Murciana-Granadina goats with 1,300 kg milk in 305 days (72), for Saanen in different countries milking more than 2,000 kg (16, 30), for Alpine in UK and Nordic goats in Norway more than 1,900 kg (30), and records of individual American Toggenburg (3,023 kg), Alpine (2,916 kg), Saanen (2,695 kg), LaMancha (2,454 kg), and Nubian (2,423 kg) have been reported (39).

Dairy goat breeds have been classified morphologically into three groups (62) (Table 2.6):

1. Short, erect ears (Swiss, Spanish, French and Nordic breeds) or no external ears (LaMancha) (Figure 2.7), and sabre-like horns, although some may be polled (Figure 2.2–2.5)
2. Short ears and outwardly-twisted or screw-type horns (Girgentana, Zalawadi) (Figures 2.12 and 2.13) or polled (Figures 2.8, 2.9, 2.11). Horn length may vary from 6 to 28 cm, up to 50 cm in Girgentana, and are longer in males (60).
3. Long or lop ears with different type horns (most tropical dairy breeds), and some may also be polled (Figures 2.6, 2.10, 2.14–2.16).

Table 2.5. Trends of Goat Milk Production during the Last 20 Years in Countries with Significant Amounts of Goat Milk Outside of the Mediterranean Region (20, 21)

	1980 1,000 MT	2001 1,000 MT	Change, % 2001–1980
AFRICA			
Burkina Faso	10	52	+420
Cameroon	—	42	—
Chad	15	32	+113
Ethiopia	94	95	+1
Kenya	74	96	+30
Mali	39	196	+402
Mauritania	70	101	+44
Niger	122	105	−14
Rwanda	9	14	+56
Senegal	10	17	+70
Somalia	282	390	+38
Sudan	467	1,250	+168
Tanzania	55	96	+74
TOTAL	***1,247***	***2,486***	***+99***
N. C. AMERICA			
Haiti	26	24	−8
Mexico	291	140	−52
TOTAL	***317***	***164***	***−48***
S. AMERICA			
Bolivia	14	12	−14
Brazil	89	138	+55
Chile	10	10	±0
Peru	19	19	±0
TOTAL	***132***	***179***	***+36***
ASIA			
Afghanistan	48	100	+108
Bangladesh	484	1,304	+169
China	113	255	+126
India	945	3,320	+251
Indonesia	—	200	—
Iran	222	385	+73
Iraq	80	54	−32
Jordan	15	12	−20
Kazakhstan	—	10	—
Kuwait	20	5	−75
Mongolia	12	35	+192
Nepal	31	60	+94
Oman	13	81	+523
Pakistan	407	607	+49
Saudi Arabia	81	71	−12
Tajikistan	-	25	-
U. Arab Emirates	7	27	+286
Uzbekistan	—	37	—
Yemen	141	120	−15

Table 2.5. Continued

	1980 1,000 MT	2001 1,000 MT	Change, % 2001–1980
West Bank	-	14 -	
TOTAL	***2,619***	***6,722***	***+157***
EUROPE			
Austria	14	17	+21
Czechoslovakia	22	26	+18
Germany	42	22	−48
Norway	26	21	−19
Switzerland	24	16	−33
Ukraine	—	194	—
USSR	303	305	+1
TOTAL	***431***	***601***	***+39***
GRAND TOTAL[1]	4,746	10,152	+114
WORLD	7,236	12,455	+72
% of world	66	82	

[1]No data available for Oceania.

Although most dairy sheep breeds vary little in type and appearance (Chapter 3, Figures 3.1–3.6), dairy goat breeds differ markedly, as shown in Figures 2.2–2.16. According to level of milk-producing ability (Table 2.7), success of genetic selection for superior mammary system, and size of population, it is appropriate to recognize the original dairy goat breeds in descending order of ranking by countries of origin as shown below (16), although admitting that some dairy goat breeds in countries such as the

Table 2.6. Goat Breeds with Dairy as Their Primary Use (62)

SHORT EARS, SABRE HORNS

Alpine, Chamoisée (Switzerland; Italy, U.K., U.S.A.)
Appenzell (Switzerland)
La Mancha (USA)
Malagueña (Spain)
Murciana-Granadina (Spain)
Nordic (Norway)
Oberhasli, Alpine (Switzerland; France, Germany, U.S.A.)
Poitévine (France)
Saanen (Switzerland; Bulgaria, China, Czechoslovakia, France, Germany, Israel, Poland, Russia, The Netherlands, U.K., U.S.A.)
Toggenburg (Switzerland; Germany, The Netherlands, U.K., U.S.A.)

SHORT EARS, TWISTED HORNS

Algarvia (Portugal)
Carpathian (Poland)
Corsican (France)

SHORT EARS, TWISTED HORNS (continued)

Garganica (Italy)
Girgentana (Italy)
Pirenaica (Spain)
Serrana (Portugal)

LOP EARS, DIFFERENT HORNS

Baladi (Egypt)
Beetal (India)
Benadir (Somalia)
Berber (Morocco)
Damascus (Syria)
Jamnapari (India)
Kamori (Pakistan)
Malabari (India)
Maltese (Italy)
Mamber (Syria)
Nubian (USA)
Sangamneri (India)
Sirohi (India)
Surti (India)

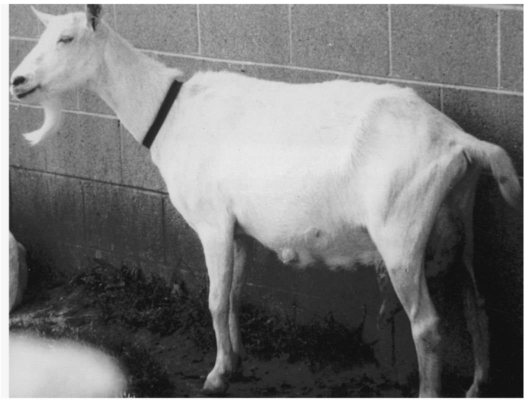

Figure 2.2. Swiss Saanen goat. Photo G.F.W. Haenlein.

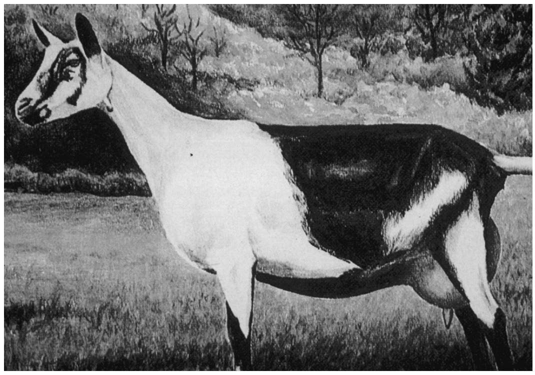

Figure 2.3. American Alpine goat. Photo American Dairy Goat Association.

Figure 2.4. American Oberhasli goat. Photo G.F.W. Haenlein.

UK, France, Germany, Norway, America, Australia, and New Zealand are distinguished by breeding success for superior type and milk production, but most of these breed populations are derivatives of imported Swiss, Spanish, or Nubian breeds:

1. Swiss breeds: Saanen, Alpine, Oberhasli, Toggenburg, Appenzell (30);
2. Mediterranean breeds:
   - Spain: Murciana-Granadina, Malagueña, Canaria, Guadarrama, Retinta Extremeña, Verata, Pirenaica, Blanca Andaluza, Blanca Celtiberica (72),
   - Italy: Maltese, Ionica, Girgentana, Garganica (89),
   - Portugal (Serrana), Greece (Native), Egypt (Nubian–Zaraibi), Syria (Damascus), Turkey (Kilis) (30);
3. Indian breeds: Jamnapari, Barbari, Beetal, Gohilwadi, Jhakrana, Kutchi, Mehsana, Surti, Zalawadi (1);
4. Other Asian and African breeds (30).