Production Systems around the World

Christian F. Gall

Centre for Agriculture in the Tropics and Subtropics, Institute for Animal Production, Hohenheim University, Stuttgart, Germany

Corresponding author: Email: christian.gall@uni-hohenheim.de

1.1 ECOLOGICAL CONDITIONS

One can distinguish between temperate, subtropical, tropical dry, tropical humid and montane conditions, each offering different possibilities for milk production, and which are the basis for different production systems (Seré & Steinfeld, 1996).

The chief dairy zones are the lowlands of the temperate climatic zone (Table 1.1). Often these receive high rainfall, which is unfavourable for cropping and the land is best used as grassland. Less than 0.5 ha may carry an animal unit (AU). Similarly, land on high-altitude mountains, for example the Alps and Pyrenees in Europe, at 1500–2000 m above sea level, is not useful for cropping because of high precipitation and short vegetation period but is used as a welcome addition to grazing by dairy animals from valley farms with limited cultivable land.

The tropical environment is generally less suitable for high-producing European dairy animals, mainly because at elevated ambient temperatures the animals need to expend energy for dissipating excess heat. Metabolic heat production is reduced by reducing feed intake and lowering metabolic rate, and this is not compatible with high milk production (Rhoads et al., 2009). As heat dissipation is mainly by water evaporation, high air humidity further aggravates the negative effects of the tropical environment. In addition, the humid tropics are not suitable for high-producing dairy animals because night temperatures mostly remain above 30°C and the metabolic heat cannot be dissipated (Preston & Leng, 1987).

Cattle of the Bos taurus genus are of little importance in the equatorial zone with extreme rainfall. Although vegetation may be abundant, with fast growth and early maturity, the plants have a high fibre content and consequently are difficult to digest and their nutrient value is low. Although increased use of the Amazonian basin for cattle-keeping demonstrates that a feed base can be created there, the preceding deforestation is not acceptable for ecological and socioeconomic reasons (Butler, 2011).

In tropical dry-lands, lack of forage due to insufficient rainfall is the limiting factor, in addition to elevated temperature. More than 400 mm rainfall is generally required to sustain cattle. In the humid savannah with 500–1000 mm rainfall, between 4 and 10 ha may be required to carry 1 AU, depending on the annual rainfall pattern. With higher and less variable rainfall only 2 ha may be required for 1 AU and only 0.5 ha on improved pasture. However, where rainfall is sufficient and feed supply is good, cattle-keeping competes with cropping for surface, capital and labour. Although average annual rainfall is not sufficient to determine the suitability of an area (because the availability of water for plant growth depends on the annual distribution pattern and the evaporation of water), it is a useful approximation. Where rainfall is extremely low and erratic, with regularly occurring extended drought periods, the feed base is insufficient to meet the nutrient requirements of cattle and more than 50 ha may be required to carry one tropical AU (De Leeuw & Tothill, 1990). Although conditions are less suitable in semi-arid and sub-humid
tropical areas, much milk is produced here because of the preponderance of small-scale farmers who depend on it. In sub-humid Africa, milk production may be hampered by disease (e.g., trypanosomiasis) but disease-tolerant breeds can be kept even for milk production (Agyemang, 2005).

Tropical highlands with temperate climatic conditions and sufficient rainfall may be ideal for cattle-keeping. Here, less than 0.5 ha may be required per AU and dairying is possible even with temperate breeds, although with a high density of human population and high soil fertility competition from cropping may leave little room for livestock, unless both operations are integrated.

### 1.2 SYSTEMS

#### 1.2.1 Small-scale milk production

Very early in history, people must have learnt to milk. Certainly boys herding the flock tasted some milk directly from the udder and milk was extracted from the udder of animals which had lost their young. Later on, this will have developed systematically, for example by early slaughter of excess male progeny. Eventually, rearing of young stock was combined with milking whatever quantity was possible without compromising the development of the young. The so-called dual-purpose system, where milk production is combined with rearing and even fattening of all male progeny, was the prevailing system in small-scale farming over the centuries and is still prevalent today in those areas where small farms dominate (Falvey & Chantalakhana, 1999).

In the past it was difficult to generate an adequate family income with agricultural activities alone on small farms (as prevails in many European countries) with limited production resources (land and capital) but possibly excess labour. Labour-intensive livestock keeping, dairy animals in particular, provided the possibility to generate additional income. Thus, dairying based mainly on pasture supplemented with agricultural by-products, was part of an integrated agricultural smallholder family enterprise in most countries. It is estimated that around 14% of the world’s population depend directly on dairy production for their livelihoods. In order to support smallholders in Europe with a view to the socioeconomic impact (on average, dairying accounts for about 20% of agricultural output in EU countries), milk production was heavily subsidised by market intervention (price support and milk quotas, see section 1.13). Similarly, in the USA the milk price was stabilised by subsidies, in Canada by milk quotas.

Even today, in the tropics and subtropics under rain-fed conditions, families living on a hectare or two cannot survive economically with crops alone. Livestock production on these farms, in addition to improving family nutrition, provides a higher return on farmers’ labour and land. Milk production allows cash to be earned daily, even with little equipment and inputs, for example a single dairy cow or some goats or a Zebu cow. Livestock also add security to the family enterprise. Even landless peasants may benefit from this opportunity. Furthermore, it is a source of organic material and soil nutrients generally lacking in such systems. Small-scale milk production of this nature can be successful with local resources (breeds, feeds, management).

Women’s smallholder dairy development in East Africa illustrates the promise that a new livestock activity can offer to a farming system under economic stress (Owango et al., 1998). Whenever conditions are improving and milk production for the market is the aim, better-responding genotypes are required that contribute earlier maturity, better reproductive function during lactation, and better milkability. While some within-breed improvement through selection works well, this is a long-term effort and its sustainability under the prevailing conditions in developing countries is rarely ensured. In particular, the necessary programmes to maintain pure Zebu (Bos indicus) breeds and strains is critical for their survival, while imported European Bos taurus breeds are more attractive for crossbreeding for milk yield improvement.

Specialised milk production is economical only if about 3500 kg milk can be sold per cow yearly. In the tropics, this performance is generally not attained with forage alone. Also, milk replacers for calf rearing are generally not available (see section 1.9). Therefore, production systems with limited milk production (approximately 1500 kg of sold milk in 300 days) combined with rearing a calf per year by the cow (with forage and limited feed supplements) are preferred over specialised dairy and meat production (Preston & Leng, 1987).

### Table 1.1. Pasture area required to sustain livestock by ecological zones in the tropics.

<table>
<thead>
<tr>
<th>Ecological zone</th>
<th>ha/tropical AU*</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperate</td>
<td>0.5</td>
<td>Grassland more suitable than cropping</td>
</tr>
<tr>
<td>lowlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical</td>
<td>0.5</td>
<td>Competition with intensive cropping</td>
</tr>
<tr>
<td>highlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical, humid</td>
<td>0.5–2</td>
<td>With improved pasture</td>
</tr>
<tr>
<td>Humid savannah</td>
<td>4–10</td>
<td></td>
</tr>
<tr>
<td>Subtropical, dry</td>
<td>&gt;50</td>
<td></td>
</tr>
</tbody>
</table>

*Tropical AU = 250 kg liveweight.

*Source: based on data from De Leeuw & Tothill (1990).*
The extent of the contribution to overall milk production by local and *Bos indicus* breeds is difficult to assess as breeds are not considered in dairy statistics of different countries. It used to be very high in Central and South American, Asian and African countries in the past, and it still will be in subsistence production systems. However, with increasing intensification and crossbreeding the contribution of local and pure Zebu breeds is diminishing.

### 1.2.2 Specialised milk production in large commercial dairies

During the 1950s and 1960s in industrialised countries, farms increasingly specialised. Farms with multiple activities tended to give up dairying as a sideline, while those continuing were becoming larger and taking advantage of economies of scale. Where optimal use of limited agricultural resources does not have to be considered, during the twentieth century dairying has developed into large specialised operations with highly productive dairy breeds, advanced technology and capital-intensive systems of production. Examples of technological innovations widely adopted by dairy farmers include (Laister *et al*., 1999; USDA, 2009):

- indoors feeding with high inputs and sophisticated feeding systems;
- elaborate animal housing;
- careful computer-assisted herd management including feeding, reproduction and health;
- modern, largely automated milking equipment in efficient milking parlours;
- on-farm refrigerated bulk milk tanks;
- mechanised waste-handling systems.

In these systems, *Bos taurus* cows may be milking up to 20 000 kg per lactation period of 305 days. Although investment in buildings and facilities, cost of feed procurement and herd management may be quite high, profitability is ensured by high production efficiency. As feed conversion is more efficient with milk production than with fattening, these farms do not consider rearing excess calves not needed for herd replacements, and they dispose of them as early as possible. Large dairy operations were established in some socialist countries: Russia, Poland, Bulgaria, Syria, Nicaragua, Cuba. Typically they comprised several units of about 100–500 milking cows each, with separate barns for calves, heifers, dry and milking cows, and milking parlours sometimes used around the clock. Other features included total mixed rations based on maize silage and alfalfa hay prepared and distributed with mobile mechanical feeders (Lammers *et al*., 2000). Similar operations can be found even in developing countries, where they supply the affluent market of the capital cities.

A minimum viable herd size is nowadays considered to be about 100 milking cows (*Bos taurus*). For instance, in the USA between 1997 and 2006 the proportion of herds with less than 100 cows decreased from 41% to 21%, whereas the proportion with more than 500 cows increased from 24 to 47% (USDA, 2008), and two-thirds of all milk was produced on farms with more than 100 cows in 2000 (Blayney, 2002). Some operations are huge, comprising several thousand cows. In 1998, the top 20 US dairies were ranked by *Successful Farming Magazine* (Looker, 1998).

The smallest of these farms had 6500 cows and the largest 18 500. The ever-increasing number of large commercial enterprises benefit from economies of scale, but raise socioeconomic concerns because they are not only crowding out small farmers, but also the agrarian and rural structure is changing (i.e. the disappearance of ancillary activities such as milk collection and artisan processing).

Recently, interest is growing in organic (biological, ecological) dairying. Regulations for official recognition differ between countries but typically stipulate the following in Europe (Borell & Sørensen, 2004; European Union, 2007b):

- half of the total feed intake, both grazing and barn feeding, must originate from the farm;
- no mineral fertilisers or pesticides may be used;
- the time period between drug administration and milking must be twice that of conventional production;
- parturient cows shall be in individual loose boxes;
- calves must receive non-processed natural milk for the first 10 weeks.

Although these practices and the produce appeal to consumers, there may be little advantage with regard to welfare, health and reproduction of the cows (Fall & Emanuelson, 2009; Langford *et al*., 2009). The number of organic dairy farms is still limited, for example less than 2% of all dairies in the USA (USDA, 2007). The cost of producing organic milk compared with conventional production was higher in 2005, but was compensated by higher sales price in most farms investigated in the USA (McBride & Greene, 2007).

### 1.2.3 Dairy ranching

In dairy ranching in the tropics, cows are kept mainly for raising young feeder stock. If their milk-producing potential exceeds the calf’s requirement, some milk may be extracted in a dual-purpose system. Local breeds or breeds crossed with imported ‘exotic’ European cattle are kept. Cattle possessing a high genetic content of Zebu are preferred as dual-purpose breeds. They are adapted to the environment, but they can be milked only in the presence of their calves. The cows are separated from their
calves in the evening, milked in the morning and spend the
day with their calves. In the evening there is no milking.
The lactation period is short. The proportion of cows
milked in a herd changes but is generally low. Milk pro-
duction varies over a wide range depending on time of the
year and feed supply. Accordingly, the contribution to farm
income of revenues from the sale of milk and from slaugh-
ter animals varies.

1.2.4 Urban dairies
Urban dairies (the term ‘dairy’ is used for both dairy herds
and milk processing or creamery factories) are situated in
the outskirts or even in the centre of major cities. They
were originally established by traders in order to meet the
demand for clean fresh milk and to avoid the risk of adulteration in the intermediate trade. The risk of disease
transmission was not considered because customarily milk
was boiled before use. The system was widespread in all
major cities until the early twentieth century. Today it is
still frequently found in India and Pakistan but more often
with buffaloes and Zebu crosses rather than with pure
European cattle. Feed is provided from owned farmland or
common land, or even purchased (Dost, 2003). City dairies
buy cows after parturition and milk them over the course of
one lactation. Calves are used only for stimulating milk
let-down and often virtually starve to death. Cows are not
bred during lactation. When dry, they are sold off either for
slaughter or for re-breeding; replacements are purchased
from breeders. Today, for sanitary reasons these dairies are
banned from cities in many regions. In India for example,
city dairies, which were quite common in most major
cities, have been banned and located out of urban areas
(deWit et al., 1996). They were replaced with varying
success by government-sponsored milk colonies or other
efficient dairy enterprises.

1.2.5 Pastoralists
The term ‘pastoralist’ (from Latin pastor, herder) refers to
livestock keepers who live entirely with and from their
animals (FAO, 2001). Typically they practise non-sedentary
systems, either nomadism or transhumance. The pasture
(common or public grazing ground) that can be grazed by
a herd is limited by the distance the animals are able to
tavel daily between night enclosure and watering points.
The number of animals a family can keep is limited by the
feed available in this area and by the available labour force.
When this herd is not sufficient to sustain a family all year
round, non-stationary systems of livestock production have
developed. In these, grazing grounds are changed at
more or less regular intervals. Pastoralism is of major
importance in sub-Saharan and North Africa, Mongolia and
Siberia. It exists to a minor extent in western, central–east
and south Asia, and in Latin America. It is estimated that
worldwide 40 million people are pastoralists (Harris,
2000). Other estimates are much higher, for example
20 million households on 25% of the world’s land surface
(Degen, 2007). However, pastoralists are increasingly
under pressure by politics and agriculturists and true
nomadic systems are becoming rare in many countries.

In transhumance systems, families settle in permanent
dwellings but move their herds seasonally between dry and wet, summer and winter, plains and mountain pastures, riverine zones flooded during the rains but offering plenty of feed in the dry season. Grazing grounds may be changed several times during the year; some may be used for only very short periods. Herds are accompanied by a few members of the family whereas the core family remains at home (Niamir, 1990). Transhumance is practised in the Mediterranean basin, in the Alps, Pyrenees, Balkan countries, in western and central Asia, in Africa and Latin America (Blench, 2001) but is limited by country border controls.

In contrast, nomads do not have permanent houses and
the whole family moves with their huts and tents following
the herds, changing locations to where forage and drinking
water are available. The rhythm of their movements is
determined by the rainfall pattern and season and the
availability of feed and water. Routes may vary between
years but movements are not erratic but rather follow
certain patterns. However, deviation from standard routes
can be frequent and is caused mainly by the erratic nature
of rainfall in dry zones but also by security considerations
(civil strife). Usually, herding groups of pastoralists claim
traditional territories but seldom have scheduled grazing
rights (Niamir, 1990). In the absence of legal protection in
the past disputes were settled by force, and this prevails
even today (Suttie et al., 2005).

In a system where animals are private property and land
is not, there is always a tendency to keep excessive animal
numbers and neglect pasture management, leading to
over-stockking and over-grazing, causing serious damage
to the vegetation that sometimes ends in desertification.
Even if there are some grazing rules in existence they are
not always respected. The lack of a feeling of ownership
and responsibility in many African countries was a result
of colonial regimes that tended to abolish all traditional
rules without replacing them by adequate pasture manage-
ment policies. Once traditional land-use rights were
forgotten, their re-establishment proved difficult (Masri,
2001) if not impossible (Niamir, 1990). In an attempt to
restore the productivity of mismanaged land, cattle
ranches have been established with individual or group
ownership of land, enabling herders to sustainably man-
age their pastures (Ng’ethe, 1992). However, this approach
failed to understand that mobility is necessary to cope with the high variation in rainfall and fodder availability, and movement outside the delineated ranch area is necessary in excessively dry periods. Also, the ranch system proved a temptation for the stronger and successful herders to crowd out the less successful and to appropriate land at the expense of others (even to the benefit of non-agricultural profiteers).

Herds are often a mixture of cattle, sheep, goats, donkeys and camels. The preferred species is determined by the type of vegetation, water availability, topography, and distances to be travelled. Sheep, goats and camels are frequent where pasture resources are particularly scarce, bush dominates, and where long distances have to be covered daily to access drinking water. Cattle provide wealth and security but also meat and milk. They are often the dominant livestock species but during and after prolonged drought periods cattle numbers will be reduced as this species suffers most from the effects of insufficient rainfall.

Access to drinking water (together with feed) is one of the basic elements of pastoralism. Lifting of drinking water for livestock from wells is labour intensive. In fact, the labour available for this activity is often the main factor limiting herd size (Cossins & Upton, 1987). Because of migration of young family members to the cities, providing drinking water is increasingly a constraint. In northern Africa with less than 200 mm average annual rainfall, livestock was reduced after repeated prolonged droughts in the 1970s and 1980s, and the nomadic system was severely affected with losses of entire herds that never were replaced afterwards. Surviving sheep and goats replaced cattle and camels. When herders were forced to sell their remaining stock (to agriculturists, traders or government officers) and did not find job opportunities outside the system (Coppock, 1994), they were lucky to continue their profession as employed herdsmen (Fratkin & Roth, 2005). However, with diminishing grazing pressure the ecological threat seems to be reducing. Because of recent changes in the relationship with agriculturalists (see following paragraphs), many pastoralists can no longer sustain their herds because of increasing scarcity of dry season grazing.

Pastoralists practise subsistence systems of production, and livestock provides the basic livelihood of the families. Milk is the staple food of these people. Milk is obtained from cattle, sheep and goats but camel milk is particularly relished. Studies in eastern Ethiopia have shown average daily milk production from camels at 9.0 kg, from local cattle at 5.4 kg and from sheep and goats at 0.45 kg by nomadic pastoralists during the wet season (Degen, 2007). With non-Muslims in eastern Africa, animal blood has been a welcome addition mainly for the young warriors herding local cattle and goats, but this habit is disappearing.

While milk supplies around 50% of energy to many pastoralist societies, some nomads live entirely on milk at least seasonally (Sadler et al., 2009). Energy is added to the protein-rich milk diet with the use of grains, either purchased or bartered. In addition, to a varying extent, pastoralists traditionally did grow some grain crops on attributed fields, for example wet pockets (depressions) in a desert surrounding where seasonally, during and after the rains, a crop could be raised. Some member of the family would stay at the fields during the cropping season. Alternatively, some of the extended families settle and completely engage in cropping (FAO, 2001).

If there is access to a market, pastoralists may even sell some excess milk and it is not uncommon for women to carry even small quantities over long distances to the market. If milk can be sold, depending on price relations, up to 16 times more energy can be obtained by purchasing grains with the proceeds. While the protein thus obtained may not have the same value as that in milk, undernourished children need energy primarily (Lynch, 1979). As individual milk yield is low (estimated at 252 kg per cow lactation) (Otte & Chilonda, 2002) and milk is rarely marketed, its importance for nutrition and household economy tends to be underestimated in nutrition statistics.

Pastoralists continue to dominate in the sub-Saharan zone experiencing 200–430 mm annual rainfall, where they keep about 24% of the total ruminant tropical livestock (Otte & Chilonda, 2002), but they are increasingly under pressure from agriculturists. Where grazing areas border cropping areas, rules are observed traditionally in order to mutually safeguard the individual interests of both pastoralists and agriculturists. Grazing grounds are delineated where cropping is not allowed, corridors are established in cropping areas to ensure access of herds to water and pastures, and periods are fixed when stubble may be grazed after harvest. Procedures are established for compensation of crop damage caused by livestock. Conflicts between agriculturists and pastoralists may be caused by violation of these rules. Conflicts are fuelled by ethnic separation of agriculturists and pastoralists. Because of population growth, agriculturists are encroaching on traditional grazing grounds, in particular those of higher precipitation, which served for dry-season grazing and retreat areas. However, grazing grounds are also lost by establishing erosion control belts, wildlife reserves and by afforestation. On the other hand, herders tend to invade cropping areas because of lack of rainfall.

Integration of animal husbandry (agro-pastoralism) with cropping is becoming more frequent in western Sahel countries, where traditionally both were strictly separated. This livestock keeping is more market oriented because for these people animals do not mainly provide security (Ndambi et al., 2007).
1.3 FEED RESOURCES

Ruminants are equipped to mobilise energy and nutrients in grass and other cellulose-rich plant material to supply their needs for maintenance, including maintenance of body temperature and for movement, and reproduction together with nursing the young. Using ruminants for milk production is reasonable mainly if they feed on resources that cannot be used directly for human nutrition, such as grass and food produced on arable land. Use is made of their capacity to feed on grass and other roughages without competition for scarce human resources and convert it into milk (Preston & Leng, 1987). Ideally, these resource-conservative feeding systems are based on range and pasture, but in developing countries also on grazing waste land, stubble fields, roadsides, canal banks, fallow, tree plantations as well as feeding on straw and other agricultural by-products. This applies particularly to countries short on resources and which have difficulties supplying basic food to their population. Where resources are not in short supply and where there is a remunerative market for milk, feeding milking animals with grains (i.e. various kinds of animal feeds with higher concentrations of nutrients and energy than grass and other roughage, such as cereals, oil cakes and other by-products of the food processing industry), even in high amounts, may be economically justified (Speedy, 2001), whereas socioeconomically it still is criticised.

Nutrient requirements for milk production over and above pure maintenance are conveniently assessed by multiples of maintenance (Table 1.2). As can be seen in this table, even with a milk yield of only 2.7 kg daily, which is about the minimum to raise a calf, 1.2 times maintenance energy (i.e. 20% more) is required. Under tropical, scarce feed supply conditions, even cows of local breeds often have difficulties meeting their maintenance requirements and it can be deduced that there is little room for improved and more productive breeds. A production level of 13.5 kg milk per day requires a doubling of energy intake, which is hard to achieve under tropical conditions. It is possible only with more concentrated feeds such as improved pasture (grass and legumes, fertiliser, irrigation), cultivated fodder (e.g. alfalfa, maize) and grains in the diet.

1.4 ANIMAL SPECIES USED FOR MILK PRODUCTION

1.4.1 Cattle

Cattle are the predominant dairy species worldwide. They produce 83% of all milk (Table 1.3), comprising more than 90% in Europe and North America but only 75% and 60% in Africa and Asia, respectively. Milk from other species is statistically negligible in industrialised Western countries, although there are niche openings for mainly small but even big producers supplying specialised markets for gourmets and health-conscious consumers (e.g. from goats, sheep, camel, mares and donkeys). Unimproved cattle breeds of both Bos indicus and Bos taurus type, which are used mainly in multi-purpose systems for meat, milk, manure and draught purposes, are adapted to tropical conditions by virtue of heat tolerance, disease resistance, better feed intake and digestion of low-quality feeds. They produce quantities of milk sufficient to raise their young, possibly even twins, but some additional milk in excess of the calf’s need may be extracted from the cows mainly for improving the family diet while small quantities may also be marketed.

In order to qualify as a dairy breed, cattle and other species must be able to produce milk well in excess of the neonate’s requirements and in addition must yield their milk to humans uninhibitedly at milking rather than by simultaneous presence or suckling by the young calf, kid, lamb, etc. Among the many hundreds of breeds listed globally, there are only a few of worldwide dairy importance (Mason, 1996).

All milk-producing animals, with exceptions where religious taboos exist, are eventually used for meat. Male calves may be a valuable asset, adding income to the dairy enterprise, but not in all production systems (see section 1.2.2). In tropical countries, almost all traditional production systems are dual (multiple) purpose, where meat and draught power are other benefits along with milk. However, the concept of dual-purpose breed would require special attention to be given to meat characteristics in selective breeding.

With few exceptions, dairy breeds comprise Bos taurus. There is a tendency towards a few highly selected and productive breeds for worldwide distribution, such as the Holstein-Friesian. The concentration on a few breeds and often on few pedigree lines within breeds is raising concern of possible inbreeding depression and loss of genetic diversity.

---

### Table 1.2. Daily energy requirements (MJ metabolisable energy) for maintenance and milk production.

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Milk yield (kg)</th>
<th>Total requirement</th>
<th>Multiple of maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>2.7</td>
<td>72</td>
<td>1.2</td>
</tr>
<tr>
<td>60</td>
<td>6.7</td>
<td>90</td>
<td>1.5</td>
</tr>
<tr>
<td>60</td>
<td>13.5</td>
<td>120</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Assumptions: Dairy cow, 359 kg liveweight, 0.75MJ ME/kg body weight<sup>0.75</sup>, 4.46 MJ ME/kg milk with 3.5% fat.

Source: based on data from National Research Council (2001).
1.4.1.1 Milk yield

The economically most important trait is the per-cow annual or lactation milk yield. It depends on daily amounts of milk and length of lactation. Length of lactation is quite variable. Milk secretion ceases when the cow is pregnant again, which may happen after 3 months, but under less favourable conditions much later. In modern dairy breeds, the cow is expected to be pregnant again 6 weeks after birth. Under normal conditions, the milk secretion of pregnant cows gradually decreases and milking is discontinued about 6 weeks before the next parturition (Svennersten-Sjaunja & Olsson, 2005). Udder secretion after parturition and following a dry period is called colostrum. Its composition differs from later milk and it is indispensable for the calf, as it conveys antibodies and essential nutrients to the calf. It is not considered milk for human nutrition according to food legislation in most countries. However, it is relished in some cultures and for special products and health formulae. Some cows, the high-producing ones in particular, may voluntarily continue lactating even until the following parturition. In order to allow a sufficient rest period and for formation of the colostrum, cows are intentionally dried off after 10 months of lactation. Consequently, lactation records are usually standardised at 305 days in order to exclude effects of different lactation length. Average lactation milk yield per cow is between 4000 and 7000 kg in most developed countries but has attained remarkable levels with highly selected breeds and in high-input systems of production. The yield of major breeds is shown in Table 1.4.

Table 1.3. World milk production (tonnes) 2009.

<table>
<thead>
<tr>
<th>Breed</th>
<th>World</th>
<th>North America</th>
<th>South America</th>
<th>Europe</th>
<th>Africa</th>
<th>Asia</th>
<th>Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>580 481 508</td>
<td>94 074 260</td>
<td>59 179 319</td>
<td>208 947 600</td>
<td>27 646 809</td>
<td>150 187 182</td>
<td>24 671 234</td>
</tr>
<tr>
<td>Buffalo</td>
<td>90 333 830</td>
<td>217 192</td>
<td>2 640 638</td>
<td>87 476 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goat</td>
<td>15 128 186</td>
<td>160 000*</td>
<td>182 440</td>
<td>2 468 861</td>
<td>3 206 195</td>
<td>8 909 416</td>
<td>40</td>
</tr>
<tr>
<td>Sheep</td>
<td>8 974 689</td>
<td>35 670</td>
<td>3 053 751</td>
<td>1 790 384</td>
<td>4 094 883</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camel</td>
<td>1 636 132</td>
<td>80</td>
<td>1 456 107</td>
<td>179 945</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>696 554 346</td>
<td>94 074 260</td>
<td>59 397 429</td>
<td>214 687 484</td>
<td>36 740 134</td>
<td>250 847 426</td>
<td>24 671 274</td>
</tr>
</tbody>
</table>

*There are no statistics available on US goat milk production. National Agricultural Statistics Service (2011) estimates total number of milking dairy goats at 232 000 in 2011; if they produce 600 kg saleable milk yearly (Milani & Wendorff, 2011), then 139 000t may be the annual production. Goat milk production in Canada was estimated at over 21 000t in 2004 (Agriculture and Agri-Food Canada, 2006).

Source: based on data from FAO (2011b).

Table 1.4. Lactation* milk yield of dairy cattle breeds (based on data from herd-book averages, 2009).

<table>
<thead>
<tr>
<th>Breed</th>
<th>Yield (kg)</th>
<th>Fat (%)</th>
<th>FCM†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black and White, USA‡</td>
<td>10 510</td>
<td>3.64</td>
<td>9 942</td>
</tr>
<tr>
<td>Black and White, Israel§</td>
<td>11 903</td>
<td>3.52</td>
<td>11 046</td>
</tr>
<tr>
<td>Black and White, Germany¶</td>
<td>8 887</td>
<td>4.07</td>
<td>8 980</td>
</tr>
<tr>
<td>Brown Swiss, USA</td>
<td></td>
<td>8 673</td>
<td>4.06</td>
</tr>
<tr>
<td>Jersey, UK**</td>
<td>5 673</td>
<td>5.39</td>
<td>6 856</td>
</tr>
</tbody>
</table>

*As length of lactation varies, a standard lactation of 305 days’ duration is generally recorded.
† FCM, fat-corrected milk allows comparison of milk yield with different fat content. FCM = 0.4 M + 15 F (M, milk yield; F, butterfat yield; all in same units, e.g. all as kg).
‡ http://holsteinusa.com/holstein_breed/breedhistory.html
¶ http://www.holstein-dhv.de/leistung.html

1.4.1.1 Milk yield

The economically most important trait is the per-cow annual or lactation milk yield. It depends on daily amounts of milk and length of lactation. Length of lactation is quite variable. Milk secretion ceases when the cow is pregnant again, which may happen after 3 months, but under less favourable conditions much later. In modern dairy breeds, the cow is expected to be pregnant again 6 weeks after birth. Under normal conditions, the milk secretion of pregnant cows gradually decreases and milking is discontinued about 6 weeks before the next parturition (Svennersten-Sjaunja & Olsson, 2005). Udder secretion after parturition and following a dry period is called colostrum. Its composition differs from later milk and it is indispensable for the calf, as it conveys antibodies and essential nutrients to the calf. It is not considered milk for human nutrition according to food legislation in most countries. However, it is relished in some cultures and for special products and health formulae. Some cows, the high-producing ones in particular, may voluntarily continue lactating even until the following parturition. In order to allow a sufficient rest period and for formation of the colostrum, cows are intentionally dried off after 10 months of lactation. Consequently, lactation records are usually standardised at 305 days in order to exclude effects of different lactation length. Average lactation milk yield per cow is between 4000 and 7000 kg in most developed countries but has attained remarkable levels with highly selected breeds and in high-input systems of production. The yield of major breeds is shown in Table 1.4. The average lactation yield of all dairy cows in the USA
was 9601 kg in 2010 (USDA, 2011). The top-producing 133 Holstein herds had an average annual yield of 13 368 kg (Kellog et al., 2001). With her very special economic situation, Israel excels over all other countries. Growth hormone (bovine somatotropin, BST or BGH) stimulates milk secretion, and can be synthesised and administered to cows for increasing milk yield. However, because of health concerns, both in cows and milk consumers, this practice is banned in most milk-producing countries except the USA (European Commission, 1999a, b).

1.4.1.2 Milk composition
Milk composition varies greatly between livestock species, and between breeds to a lesser extent (Table 1.4). It is often observed that milk from Bos indicus or other species is superior in composition, and fat content in particular. However, there is a general tendency for milk to be more concentrated when low in quantity and during the course of the lactation: as quantity declines, component concentrations increase (Pirchner & Nibler, 2000), so that differences in fat content tend to disappear when milk production is compared at an equal milk yield basis and only full lactation data are useful.

In addition, some components like butterfat are modified by feeding. Therefore, values of the main components serve only as an indication of approximate differences between species. The data in Table 1.5 are extracted from several sources in the literature and based on personal observations. Over time, specific milk constituents have received different consideration. With cattle in particular, breeders have tried to elevate fat and protein content, especially where cheese production from milk is of major interest. However, high fat and protein percentage is not economically important under all conditions. Milk plants may pay little or no attention to differences in fat content if they market mainly fluid milk. However, if milk is mainly processed into products, the price paid to the producer is generally based on the fat and often protein content. Therefore, breeders aimed for high fat and protein content, although this was a misconception as it was the quantity of fat that producers were paid for, which is determined by both fat content and milk quantity. In Europe in particular, for a long time the goal was a minimum of 4% fat. This changed only when creameries included volume as a negative factor in their price formula. Surprisingly, in North American Holstein-Friesians where less attention was paid to fat, average fat content was not much lower (Table 1.5). Also, the negative relationship between milk quantity and fat content (Pirchner & Niblet, 2000) has to be taken into consideration when trying to increase fat percentage by selective breeding. In areas where milk is processed to butter or ghee, Jerseys or water buffaloes (breeds with high milk fat) are advantageous, whereas city fluid milk dairies prefer a high proportion of high-yielding dairy breeds even if their milk has low fat content.

1.4.1.3 Milk production in the tropics
Milk yield is generally low in the tropics because of insufficient nutrient supply, husbandry conditions (milking technique, suckling of calves) and genetic disposition. The main cause of reduced milk yield under heat stress is reduced feed intake, but direct metabolic effects of ambient temperature may also be involved (Rhoads et al., 2009).

In traditional systems where local cattle are milked while the calf is sucking, the annual saleable milk production per cow may be only about 1000 kg or less (Preston, 1991), but with improved local breeds it may be as high as 3000 kg, and even more with intensive production conditions. Milk production per hectare and year on natural pastures is about 1000–1600 kg. On grass and legume pastures it may reach 5000–9000 kg. On intensively fertilised and irrigated pastures it might be even higher (Trujillo, 1991). When comparing milk yield between animals in the tropics the calving season has to be taken into account because of seasonality of feed supply and its influence on milk yield.

Understandably, breeders in the tropics have tried to increase milk production with dairy breeds of European origin. In general, the performance of specialised dairy breeds of Bos taurus in the tropics lags behind that in temperate environments, mainly because the feed requirements of large cattle can hardly be met by smallholders (Preston, 1991).

Table 1.5. Milk composition (%; averages and ranges) of cattle, buffalo, camel, goat and sheep.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cattle</th>
<th>Buffalo</th>
<th>Camel</th>
<th>Sheep</th>
<th>Goat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>13</td>
<td>17–19</td>
<td>7.0–10.7</td>
<td>16–20</td>
<td>11.5–13.5</td>
</tr>
<tr>
<td>Fat</td>
<td>3.4–5.4</td>
<td>7.0–8.5</td>
<td>2.9–5.4</td>
<td>5.0–8.0</td>
<td>3.5–8.0</td>
</tr>
<tr>
<td>Protein</td>
<td>3.5–4.0</td>
<td>3.6–4.6</td>
<td>3.0–3.9</td>
<td>5.0–6.5</td>
<td>2.8–3.0</td>
</tr>
<tr>
<td>Lactose</td>
<td>4.6</td>
<td>4.6–5.0</td>
<td>3.3–5.8</td>
<td>4.4</td>
<td>3.9–4.4</td>
</tr>
</tbody>
</table>

Source: based on data from Park & Haenlein (2006, 2010).
As a consequence, growth rate, mature weight and fertility are generally low, and calf losses and mortality rate are high. This is accentuated by low feed quality and poor animal management. However, with adequate feed and management, milk production can be increased by crossbreeding local cattle with European dairy breeds (Cunningham & Syrstad, 1987). However, the proportion of dairy breed genes in crossbreeding must not exceed 50%, otherwise adaptation to tropical conditions will be compromised.

Under favourable tropical environmental and husbandry conditions, in tropical highlands in particular, dairy breeds can be kept successfully. More intensive forms of dairy production with adequate nutrition and management, including sometimes cooling with fans or water and low disease challenge, frequently achieve high milk yields, for example Holstein-Friesians in California, Arizona, Israel, Italy and Mexico (Table 1.4) and in peri-urban herds around many tropical capitals (de Leeuw et al., 1999). However, the economics of such operations depend largely on input–output cost relationships.

While most of the milk worldwide is produced by Bos taurus breeds, some is still produced with local, mainly Bos indicus and crossbred cattle. In tropical and subtropical Asia the majority of cattle comprise Bos indicus (Zebu, Brahman). They are kept mainly for draught, meat and manure. Characteristic traits include a hump, large dewlap and sheath fold, large hanging ears, sloping pelvis, fine legs, fine and smooth hair but, most importantly, heat tolerance and tick resistance (Berman, 2011). Examples of Bos indicus dairy breeds include the Red Sindhi, Sahiwal, Gir (Stonaker et al., 1953), Kankrej, Rath and Tharparkar in India and Pakistan, Guzerat and Gir in Brazil, and Fulani in western Africa (Madalena, 2002).

Mainly because of their adaptation to the tropical environment they are also used outside their Asian area of origin. Milk yield can be low in most Zebus and milkability is not efficient. Sucking by the calf prior to milking or at least presence of the calf at milking, is necessary with most Zebus in order to achieve sufficient milk let-down and milk flow. Milkability is related to persistence of daily milk yield, and cows lacking good genetic dairy characteristics may cease lactating as early as 100 days after parturition. However, some Zebu cows handled very carefully may be milked even without the calf being present, at least after the first weeks of lactation. Also, Zebus respond to genetic selection for milk yield, milk composition, udder conformation and milkability (Hayman, 1977). There are important populations of Guzerat (Peixoto et al., 2006) and Gir (Gaur et al., 2003) in Brazil that have been developed to be productive dairy animals by pure breeding, and of Sahiwal in Kenya, Africa (Trail & Gregory, 1981). Average 10-month records in Jamaica for Sahiwal Zebus have been reported at 2185 L over 260 lactations, for Fulani Zebus at 756 L over 1030 lactations (McLaren, 1972). Average lactation yields of six Zebu populations in India ranged from 1403 to 1931 kg for a lactation length of 257–351 days; for 27 431 Gir and 2298 Guzerat Zebus in Brazil, 2278 kg and 2400 kg for a lactation length of 291 and 285 days, respectively; and for 17 292 Sahiwal Zebus in Pakistan, 1522 kg for a lactation length of 256 days (Madalena, 2002).

### 1.4.2 Sheep and goats

Worldwide, about 3.5% of all milk is produced by goats and sheep, both referred to as small stock. This term relates not only to the size of these animals, but also to a notion of their value. Worldwide there is a tendency to value cattle higher than small stock and this reflects on the social status of the owners. However, in some areas small ruminants are valued for their specific products, and are kept even when cattle husbandry is possible or practised. Examples of this kind of small ruminant husbandry can be found in:

- France, Italy, Spain, Portugal, Greece, Norway and some other European and Mediterranean countries where milk for cheese processing is produced by sheep and goats, sometimes in intensive systems;
- Near and Far East, where milk and dairy products from sheep and goats are preferred over those from other animals;
- Islamic countries, where lambs and kids play an additional important role in religious feasts and holidays. Jewish and Islamic populations do not eat pork, while Buddhist populations do not eat beef from European (Bos taurus) breeds.

Goat and sheep milk is mainly processed into cheese and fermented products (yoghurt). Sheep breeders were the first in France to obtain the label ‘AOC’ (Appellation d’Origine Contrôlée) for Roquefort cheese (Ministère de l’Agriculture et de la Pêche, 2001). The Confédération Générale des Producteurs de Lait de Brebis et des Industriels de Roquefort successfully defends the label with a strong legal department (Roquefort 2011). Another 10 sheep and about 20 goat cheeses have obtained the EU label ‘Protected Designation of Origin’ (Designation of Origin, 1999) and thereby secured market advantage. Also in Europe, goat breeders benefit from the fact that goat milk production is not controlled by the quota system (see section 1.13).

Small ruminants are very adaptive and can stand both cold and hot climates. Small ruminants require only limited resources. In developing countries, in small herds they contribute to the sustenance of poor families and the supply of local markets, and are a way of investing surplus cash...
from cropping. Because the animals can be readily sold, the capital is available at any time. Interest accrues through growth and reproduction, although the risk (loss due to disease, death, predators or theft) may be high.

Small ruminants can be kept on extensive range with scarce feed supplies as well as intensively with high feed input. They utilise pasture, fodder and shrubs that are not suitable for cattle, such as on mountain ranges, steeply sloping land, dry steppe and desert, and marginal, residual and fallow land, and can utilise agricultural by-products. Small ruminants are not usually kept as the sole livestock in many countries, except for desert areas; more often they are kept with cattle and other species by the same owner.

Some goat breeds are true single-purpose dairy animals, especially the so-called Swiss goats, the Saanen, Alpine, Toggenburg, and Oberhasli, besides the La Mancha, Manchego, Nubian, etc. In relation to their body size and feed intake, goats equal dairy cattle even when compared at high production levels (Table 1.6). The milk yield of a 65-kg goat (about 1000 kg lactation total) equals that of a 680-kg cow (6100 kg lactation total) when compared on the basis of metabolic body weight, because metabolism is not related to body mass linearly but is proportional to the ¾ power of body mass. Also, the energy requirements to produce milk are about the same. In addition, the milkability and lactation persistence of goats can be excellent and mechanical milking is practised in many countries. The best dairy goat breeds are of Swiss origin. Some of them have been used worldwide to improve local breeds. Best known is probably the Saanen, which attains herd yield averages of 1000 kg per lactation. Using genetic selection for milk yield, individual dairy goats in the USA have achieved daily production levels of 6–12 kg with twice daily milking, producing up to 3620 kg over a 305-day lactation (Haenlein, 2007). On a 4% FCM (fat-corrected milk) basis, the records were 2380 kg for a La Mancha, 2438 kg for an Oberhasli, 2506 kg for a Saanen, 3150 kg for a Nubian, 3266 kg for an Alpine, and 3578 kg for a Toggenburg, approaching or equalling the highest producing Holstein dairy cows.

Similarly, some sheep breeds have achieved fairly high milk yields (Table 1.6). The normal lactation period is however only around 200 days. Although their milkability, especially their udder conformation, does not yet equal that of cattle or goats, technology exists for efficient mechanical milking. There are two excelling breeds, the East Friesian milk sheep and the improved Israeli Awassi, which produce on average 500–600 kg per lactation, and some dairy sheep have produced more than 1000 kg per lactation, which on a total solids basis equals that of high-producing dairy goats (Haenlein, 2007).

### Table 1.6. Milk yield of goats and sheep.

<table>
<thead>
<tr>
<th></th>
<th>Milk yield (kg)</th>
<th>Fat content (%)</th>
<th>Days of lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat†</td>
<td>160–1900</td>
<td>3.5–8.0</td>
<td>305</td>
</tr>
<tr>
<td>Sheep‡</td>
<td>160–600 (900)</td>
<td>5.3–9.3</td>
<td>270</td>
</tr>
<tr>
<td>Sheep, Improved Awassi³</td>
<td>506</td>
<td></td>
<td>214</td>
</tr>
</tbody>
</table>

**Sources:** based on data from †Park & Haenlein (2010); ‡Haenlein & Wendorff (2006) (900 kg were recorded in a 365-day lactation period); §Gootwine & Pollott (2000).

Buffalo (water buffalo, *Bubalus bubalis*, not to be confused with the American bison, *Bison bison*, which is commonly referred to as buffalo) are widely used as dairy animals in Asia, India and Pakistan in particular, where their milk is highly valued. Probably more people depend for milk on water buffalo than on any other livestock species in the world (Kumar *et al.*, 2006), although the same can be claimed for goats but reliable statistics do not exist. Buffalo milk is preferred over cow milk because of its taste and high fat content. Buffaloes are also kept in some Latin American countries (notably Brazil, Argentina and Venezuela), and there are buffalo populations in Egypt, eastern Europe (Bulgaria, Romania and the former Yugoslavia), Iran, Iraq and Turkey. In Campania, Italy, buffaloes are kept in a shed under intensive management conditions for the production of Mozzarella di bufala cheese, which is protected by the Denomination of Controlled Origin (DOP) (European Union, 2008). It is defended by the Consorzio di Tutela della Mozzarella di Bufala Campana (Repubblica Italiana, 2011). Buffalo milk does not fall under the EU quota system.

The buffalo is well adapted to the hot tropical environment but needs shade or wallow during the heat at noon. It consumes and converts fibre-rich roughage, such as straw. Milkability is limited and the presence of the calf is necessary in order to stimulate milk let-down, at least during the early part of the lactation, but breeds and technological
systems exist where milking machines are applied. There are many breeds in Asian countries, with nine well-described breeds in India alone: Bhadawari, Jaffarabadi, Mehsana, Murrah, Nagpuri, Nili-Ravi, Pandharpuri, Surti and Toda. Liveweight is between 500 and 600 kg (Table 1.7). Milk yield during a 270–350 day lactation, followed by a 140–300 day dry period, is between 500 and 2100 kg per lactation (often exceeding that of local cattle in tropical countries) with 4.5–8.6% fat content. Under intensive management in Italy, milk yield achieved up to 5061 kg with 8.6–10.3% fat in a 270-day lactation (Rosati & vanVleck, 2002).

### Table 1.7. Milk production of water buffalo.

<table>
<thead>
<tr>
<th>Country/breed</th>
<th>Body weight (kg)</th>
<th>Milk (kg)</th>
<th>Fat (%)</th>
<th>Lactation length (days)</th>
<th>Calving interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India, Murrah</td>
<td>495</td>
<td>1800</td>
<td>7.5</td>
<td>305</td>
<td>479</td>
</tr>
<tr>
<td>India, Nili-Ravi</td>
<td>546</td>
<td>2000</td>
<td>6.5</td>
<td>305</td>
<td>443</td>
</tr>
<tr>
<td>India, Pandharpuri</td>
<td></td>
<td>1142</td>
<td>7.0</td>
<td>305</td>
<td></td>
</tr>
<tr>
<td>India, Surti</td>
<td>550–650</td>
<td>2090</td>
<td>6.6–8.1</td>
<td>350</td>
<td>510</td>
</tr>
<tr>
<td>Pakistan, Nili-Ravi</td>
<td>625</td>
<td>2070</td>
<td></td>
<td>312</td>
<td></td>
</tr>
<tr>
<td>China*</td>
<td></td>
<td>2262</td>
<td></td>
<td>316</td>
<td></td>
</tr>
<tr>
<td>Egypt†</td>
<td>300</td>
<td>1850</td>
<td></td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>650</td>
<td>2221</td>
<td>8.1</td>
<td>270</td>
<td></td>
</tr>
</tbody>
</table>

*Mainly Murrah and Nili-Ravi.
†Borghese (2010).

Source: based on data from Borghese (2005).

1.4.4 Camel

The Arabian or one-humped camel (*Camelus dromedarius*) is an important milk animal in pastoral systems in semi-arid northern and north-eastern Africa (Sahel), on the Arabian Peninsula and the Indo-Pakistan subcontinent (Rajasthan in particular). Many people in these areas seasonally depend on camel milk and take a specific liking to the camel, which plays an almost mythical role in their lives (Lhoste, 2004). Camels are kept mainly where environmental conditions (temperature, water availability, feed quality) do not favour cattle-keeping. Here, they may produce more milk than cattle. Camels are milked in the presence of the calf. As the cistern volume is very small, frequent milking is necessary (three to four times daily). Milking begins typically 3 months after parturition and may continue for 12–18 months. Camels continue lactating even when water availability is restricted (Bekele *et al*., 2011). Milk yield varies depending on environmental conditions (Faye, 2004). Data in the literature vary greatly and are difficult to compare as conditions influencing records are not always stated (frequency of milking, milk suckled by the young included or not, length of lactation, calving interval, feeding, field or experimental data). Average daily yield of 1–2 kg and 1000–1500 kg per lactation (Kaufmann, 1998) can be expected but with feed supplementation 6 and even 12 kg per day have been reported.

There is a luxury market on the Arabian Peninsula and in North African countries. Some intensive camel dairies benefit and produce close to urban centres. Although the main herd continues under pastoral management, some lactating camels are fed intensively for about 12 months and milked with machines, with milk let-down sometimes stimulated with injections of oxytocin, the hormone that causes milk to pass from the secretory tissue into the holding cistern of the udder (Balasse, 2003).

The double-humped camel (*Camelus bactrianus*) is adapted to both the extreme hot and cold climates of northern deserts and is kept in transhumance systems mainly in central Asia’s steppe regions. Although kept mainly as a pack animal and producer of fine wool, it is also milked. The milk is a traditional staple food, especially in Mongolia (Gobi desert). Average milk yield during an 18-month lactation is reported to be 174–576 L (Saipolda, 2004) but can reach 15–20 kg daily during peak lactation and 1000–1500 kg in a 305-day lactation (Baimukanov, 1989). The milk is used to make butter, cheese, curd, yoghurt and other fermented products.

1.4.5 Mare

Traditionally, mares are milked in some central Asian countries: Mongolia, Kirgisia, Kazakhstan, Kyrgyzstan and Byelorussia. Mares’ milk is an important asset for pastoral people, accounting for about 8% of all milk produced. Along with other exotic livestock, mares are kept for milk in many industrialised countries, producing mainly for the
fad or health food market. Many breeds are milked but heavy horses are preferred in specialised dairies, where in Europe the Haflinger breed with its excellent milkability characteristics is more frequently used (Zollmann, 1985; Doreau & Boulot, 1989; Park et al., 2006).

Mares are usually hand milked in the presence of the foal to stimulate let-down, at least at the beginning of lactation. In specialised operations machine milking is practised. Frequent milking (more than twice daily) is necessary because the cistern volume is small. Under natural conditions mares nurse their foals for up to 12 months, while milking lactations last for about 6 months, sometimes even 9 months. The mare’s average daily milk yield is 10–15 L (Doreau & Boulot, 1989). Annual milk production (generally in a 6-month lactation) can be 1500–2560 L of marketable milk (Kosharov et al., 1989). Milk is mainly processed into fermented milk products; Koumiss, popular in Russia and Asia; Airag in Mongolia, results from some alcoholic fermentation.

### 1.4.6 Yak

The discussion in this section relies heavily on Wiener et al. (2003/2006). The taxonomy of the yak is not quite clear, but there is a tendency to classify it as a species (Poephagus grunniens or Bos grunniens) of the genus Poephagus (belonging together with Bos and Bison to the Bovinae; Olsen, 1991). With 60 chromosomes, the same as Bos taurus and Bos indicus and Bison, the yak interbreeds with both; the female offspring are fertile but the males are not (Deakin et al., 1935).

Yaks are adapted to low temperatures, high altitude (low oxygen pressure), high solar radiation and scarce vegetation. On their own, they prefer grazing at altitudes between 4000 and 6000 m above sea level. Yaks are typically husbanded between 2500 and 5500 m, mainly above the treeline, with cool moist summers and severely cold winters. There is frost all year round with a very short growing season. Yak husbandry is part of the social and cultural life of the people living at these inhospitable altitudes.

Yaks are kept in the Himalayan mountain range, predominantly on the Qinghai–Tibetan Plateau and other regions around the Himalayas (Wu, 2003/2006), where many prosperous pastoral groups still exist (Sarbagishev et al., 1989) Yaks are also kept in the high-altitude areas of the republics of central Asia, mainly in Kirgisia, Tajikistan, northwest China, Mongolian People’s Republic, Nepal and Tibet. Small numbers are kept in India, Bhutan, Afghanistan, in the north Caucasus and in southern Siberia and Yakutia.

Yaks in Mongolia are kept in a pastoral transhumance system, herds alternating between low (cold season pasture) and high mountains (warm season pasture), but recently more herders have settled. Although this has merit in providing an infrastructure for the community and raising the standards of social services for yak herders, it entails the problem of land degradation (Wu, 2003/2006). The yak is not a dairy animal but traditionally herders take milk for domestic consumption and milk is the most important of the yak products. The yak is milked in the presence of the calf. Yield is estimated between 1 and 3 kg daily during the five summer months. Fat content is 6–7% (Dong et al., 2007). Milk is consumed fresh or processed into butter, fermented products and cheese.

### 1.4.7 Reindeer

This section is based on information from Holand et al. (2006) and Vistnes et al. (2009). The reindeer (Rangifer tarandus), or caribou in North America, is an arctic and sub-arctic deer. Reindeer herding can be dated at least as far back as the late Iron Age. Reindeer are herded by Eurasian arctic and sub-arctic people including the Sami, also known as Laps (in Norway, northern Sweden, and neighbouring Russia), the Nenets (in the polar regions of north-east Europe and north-west Siberia) and the Inuit (in Canada and Siberia). Traditionally, reindeer herders migrate with their herds between coast and inland areas following annual routes. Reindeer are raised in the taiga and tundra for their meat, hides, antlers, transportation and, to a lesser extent mainly in the taiga, for milk. They are the only source of milk because no other milk animal can live in these zones. Milk is consumed fresh or processed. There is evidence that milking reindeer was important for the northern nomads but it was abandoned early in the twentieth century except in south-eastern Siberia and Lapland (Holand et al., 2006). Reindeer are not fully domesticated and do not breed in captivity, but they were tamed for milking in northern Norway/Lapland. Average milk yield is between 100 and 500 g daily, with about 100 kg per lactation.

### 1.5 BREED IMPROVEMENT

Animal husbandry is inextricably related to selective breeding. All those characteristics necessary for environmental adaptation, survival, reproduction and population growth have developed with evolution, whereas the traits necessary for purposeful production had to be increased with domestication. In the case of milk production these were milk yield and milkability, but also all predisposing traits like docility, precocity, reproductive rate and feed intake. The quantity of feed needed for high levels of milk production requires an animal that is eager to feed plentifully. In selecting for all these productive traits the original adaptive traits must be conserved (Menjo et al., 2009).

This may seem self-evident, but with increasing protection of livestock (housing and healthcare), improved nutrition,
Livestock breeding is beset with the problem that not all desirable traits can be combined. Some traits may even be linked with undesirable characteristics (Clark, 1998). Examples of antagonistic traits in dairy cattle include early maturation and longevity (Essl, 1998), milk yield and fat content, milk yield and reproductive efficiency, and milk yield and meat production in dual-purpose cattle. Careful economic evaluation and giving appropriate weight in selection indices can tackle the problem (Pearson & Miller, 1981).

1.5.1 Pure breeding

With the inherent low reproductive rate of cattle, the potential to select among cows is limited and breeding efforts concentrate on sires. Traditionally in the past, sires were selected on the basis of their dam’s quality and on physical appearance. Although all the physical traits of an animal (phenotype) result from gene action (genotype), the progeny of superior individuals does not necessarily exceed the average population. Thus, selection on the basis of individual merit understandably yields only slow progress. Attempts to assess a sire’s breeding value on the basis of daughter performance can already be seen in the eighteenth century but systematic science-based methods to estimate breeding value began only in the twentieth century. As genes are transmitted to the progeny randomly, large numbers of progeny are necessary for reliable estimates (Lush, 1937). Pure breeding has dominated the development of the superior European dairy cattle breeds and crossbreeding has not been practised widely, except in the tropics.

1.5.2 Artificial insemination

Substantial progress in breed improvement came with the advent of artificial insemination (AI) (van Vleck, 1981). Because with AI one sire could produce thousands of progeny, the number of sires needed was much less and they could be selected much more rigorously. In addition, expensive shipping of live breeding stock was obviated and worldwide gene transfer was facilitated. Today, European dairy cattle are almost exclusively bred through AI and the breeding value of all sires is estimated with elaborate methods and a high degree of accuracy, which allows their ranking for expected progeny performance (Pearson & Miller, 1981).

AI is much less common in other dairy species, although practised to a limited extent in goats, sheep, buffalo and even the mare. Even in tropical developing countries AI is regularly applied in dairy cattle. However, the elaborate system required is not always available and deficiencies in the system may cause low conception and calving rate.

1.5.3 Embryo transfer

Transfer of embryos (following stimulation of multiple ovulation) into foster mothers (multiple ovulation and embryo transfer or MOET) makes it possible to obtain from outstanding dams more progeny than they could raise naturally. It also means much lower transportation costs in the export business. This led to further improvements in genetic progress by more accurate and intense selection and shorter generation intervals (Teepker & Smith, 1990).

1.5.4 Genomic selection

Recently, additional selection response is being achieved by genomic section (Hayes et al., 2009; Goddard et al., 2010). Following sequencing of the bovine genome, many DNA markers in the form of single-nucleotide polymorphisms (SNP) have been discovered. Genomic breeding value (GEBV) is computed using a reference population of animals that have high-density genotype as well as phenotypic information (de Roos et al., 2011; Weller & Ron, 2011). The genomic breeding value can be predicted at birth, thus largely enhancing genetic gain by reducing the generation interval.

1.5.5 Crossbreeding

Genetic improvement through selection for milk yield within breeds is a tedious long-term process. Therefore, breeders often take to crossbreeding (Taneja, 1999). Crossbreeding was frequent in the early stages of developing a breed. This can be a single introduction of a certain trait not present in the original breed but available in another breed by using one or a few sires for one or a few generations followed by selection for the new trait in subsequent generations. Alternatively, two breeds can be combined to form a new breed which carries desirable traits of the two. Though often claimed, the superiority of individual dairy breeds for crossbreeding is insufficiently proven (choice of breed very much depends on experts’ personal experience with a particular breed). However, the use of well-established breeds with large populations in their homeland is to be preferred for organisational reasons. Thus, Black and White cattle (Holstein-Friesian), as
also Saanen goats and East Friesian dairy sheep, have been used worldwide for crossbreeding.

In tropical countries where local cattle are poor milk producers, it was often tried to increase their milk yield by using European dairy breeds. However, because these European breeds are insufficiently adapted to the environment, they perform well only with high inputs. Therefore, European breeds are crossed with local breeds so as to produce mainly half or three-quarter crossbreeds (i.e. containing half to three-quarters of the genes of dairy breeds) (Mason & Buvanendran, 1982). Provided feeding and management are adequate, the milk yield of these crosses can be satisfactory. This process is difficult for smallholders, and there is the problem of maintaining the appropriate gene proportion. In addition, there is the danger of valuable genetic resources being lost. Therefore projects for increasing milk production by genetic improvement often failed.

Several synthetic breeds were formed by crossing bos taurus with bos indicus cattle in order to sustainably combine the dairy characteristics of temperate breeds with the adaptation (heat tolerance, disease and tick resistance) of tropical breeds (Wellington & Mahadevan, 1977; Taneja, 1999; Madalena, 2002). However, among many attempts only a few were sustainable (Mason, 1996). Examples of successful programmes are crosses between Zebras and dairy breeds in Jamaica and Australia. The Jamaica Hope was developed with Jerseys and Fulani Zebras. Howe (1949) had shown that crossing with Zebras could improve growth rate, milk yield, milk fat content and reproductive efficiency of bos taurus cattle. Milk yield of 269 Zebu-Jersey crossbreed lactations was 1489 L, and of Zebu-Friesian crossbreeds 2143 L over 77 lactations (McLaren, 1972). The breed was officially recognised emphasising their heat tolerance, and fertility combined with high milk yield (Lecky, 1951). A breed society was formed with about 50 members. From 1950 to 1964, milk yields of 2153 305-day lactations averaged 2676 kg (McLaren, 1972). While some Jamaica Hope cattle were exported to Caribbean and Latin American countries, the breed has not experienced widespread use. Dairy producers apparently prefer the more productive Holstein-Friesian benefiting from support by a strong breeders association. The extra cost for management and health care is offset by additional income. The Australian Friesian Sahiwal (APS) contains 50% each of b.taurus and b. indicus. Under good Queensland conditions it produced 2749 kg milk and 115 kg fat against 3670 kg and 141 kg by Holstein-Friesians. But under wet tropical conditions APS milk and fat yield excelled over the Holstein-Friesian by 124 and 141%, respectively (Taneja, 1999). The Australian Milking Zebu (AMZ) was developed with 20 to 40% Bos indicus (Sahiwal, Red Sindhi) and 60 to 80% Jersey. Milk and fat yield of AMZ (3304, 146 kg), Guernsey (2913, 124 kg) and Friesian (4165, 138 kg) were comparable under favourable environmental conditions. But AMZ excelled in heat tolerance: exposure to 36–40.5°C reduced milk yield by 30% in Friesians but less than 5% in AMZ (Hayman, 1977). Similar crossbreeding efforts have been made in Venezuela and Cuba (Madalena, 2002).

1.6 NUTRITION

Herbivores, as the term implies, live on plant material. The preference of livestock species for plant families differs. Some select nutrient-rich, easily digestible matter (e.g. sheep and goats) while others content themselves with fibre-rich roughage of lesser digestibility and nutrient density (e.g. buffalo). However, all are able to metabolise plant nutrients into milk. Efficiency of feed net energy conversion into milk is very similar in all species but depends largely on the energy density of the feed (Van Soest, 1994). Traditionally, all herbivore livestock were allowed to graze. Where environmental conditions did not allow year-round grazing, hay or silage was prepared for winter feeding. With good feeding management a cow can produce about 4000 kg milk per lactation on the basis of quality roughage alone (grass, hay, silage). With increasing production, feeding of concentrates becomes necessary. These will add protein and energy. As a rule of thumb, 1 kg concentrate will provide nutrients for about 2 kg milk. The feed requirements of high-producing cows are remarkable and it needs a cow willing to eat great quantities and a herdsman able to handle the art of prudent feeding. A cow of 454 kg liveweight producing 30 kg milk will have to eat as much as 13 kg dry matter daily (National Research Council, 2001). In order to produce 8000 kg per lactation, a cow will need in addition to roughage about 2000 kg concentrates. As long as the price relation between milk and feed are favourable, even feeding such high quantities of concentrates can be economical (Williams et al., 1987).

For proper functioning, the rumen needs a large microbiota population to ferment the dietary fibre, so feeding such quantities of concentrates (containing little fibre) can easily disturb the fragile equilibrium of the microbiota in this dynamic organ. Depending on the mineral (and micronutrient) content of feeds, it may be necessary to supplement the rations with these substances. Supplying a balanced diet with all the nutrients (protein and energy but also minerals and micronutrients) to meet the demand for production without provoking metabolic disorders is a challenge for the dairyman.

In the twentieth century, keeping cows in confinement year round and feeding maize silage (supplemented with protein) became the predominant system, mainly because higher yields per hectare were achieved and herd management
1 / Production Systems around the World

was simplified. Alternatively, alfalfa (or grass) may be the main roughage; in this case, energy must be supplemented. However, recent research has indicated that the healthier pasture grazing system, even though producing less milk yield, may fare better economically than production in confinement (White et al., 2002).

What has been said about cattle applies mutatis mutandis to other species as well but high feed input may not be appropriate with all species and in all production systems, unless genetic ability has been provided by selection.

1.7 ANIMAL HEALTH

Many livestock diseases can impair animal well-being, reproduction and production. Physical injuries and fractures are not specific to dairy animals but joint injuries and distortions may be caused by inadequate housing conditions, for example a slippery loafing area in free-housing (Webb & Nilsson, 1983). Infectious and transmissible (bacteria, virus) diseases as well as endo- and ecto-parasites are a menace wherever animals are kept in great numbers. Crowding animals in houses and on pasture increases the risk of disease transmission (Lean et al., 2008). Youngstock prior to weaning are particularly susceptible. Blood parasites transmitted by insects and ticks are a great problem in the tropics to the extent that some areas where these are endemic may not be usable by livestock except for resistant breeds and species (e.g. trypanosomiasis in Africa) (FAO, 1992), or continuous expensive preventive measures may be necessary.

Considerable effort is necessary to prevent negative effects and keep livestock healthy. The importance of disease varies with animal management (nutrition in particular) and environmental conditions. A hot and humid tropical climate favours diseases but in the tropical highlands disease pressure is much less and even high-producing dairy animals may be kept.

High-yielding dairy animals are particularly prone to diseases. Metabolism, reproductive functions and the mammary gland are under heavy stress. Special care is therefore required to protect these organs and systems from negative effects or even from collapse. Although disease incidence in herds with fewer than 100 cows has been found to be less than in larger herds, the risk of mortal disease does not seem to be increasing with herd size (USDA, 2007). Among 30 endemic livestock diseases, mastitis causes the highest economic cost followed by lameness (Bennett, 2003). In a selection experiment where two lines were established, with average and high milk yield (5753 vs. 6693 kg per lactation, respectively), it was shown that the high yielders incurred higher cost for mammary problems but less cost for reproductive problems (Dunklee et al., 1994a, b). Thus, careful herd management and close surveillance can check the impact of disease even in large herds with high levels of production. However, the total cost of diseases (over and above direct veterinary expenses) is difficult to assess, but is reflected largely in the cost of reduced lifetime production (see section 1.13).

Immunisation (vaccination) is possible against various infectious diseases, and some of these interventions are obligatory in certain countries. Some diseases are eliminated in many countries (tuberculosis, brucellosis) or even eradicated worldwide (rinderpest). Controlling disease-transmitting vectors (e.g. insects, ticks) and breaking the cycle of gastrointestinal parasites are essential preventive measures.

Moreover, certain diseases (zoonoses) are common to animals and humans (Table 1.8). Raw milk is the main route of transmission but other animal products and contact are also involved. Keeping livestock in close proximity to concentrations of humans increases the risk of transmitting these diseases. Special care with disease prevention is therefore necessary (see also section 1.12.2). Recently, new diseases have emerged that seriously affect livestock and may even be transmitted to humans. Bovine spongiform encephalopathy (‘mad cow disease’) has received much attention because of a possible link with the life-threatening Creutzfeld–Jakob disease of humans (Kimberlin, 1993). Although tuberculosis has been eliminated in most industrialised countries, it is still a major killer in many tropical countries and mainly transmitted by raw milk. Rift valley fever may also be transmitted by milk from animals (Konrad et al., 2011). Infection of humans is rare but mortality rate in those infected is high (World Health Organization, 2007).

1.8 REPRODUCTION

Physiologically, milk production is part of reproduction, because it allows nutrition of the newborn. Dams secrete milk following parturition. Therefore, regular pregnancy is an essential precondition for herd productivity in milk production systems. In addition, dams should continue milk secretion when they become pregnant again. Originally, in most mammals the hormonal effects during nursing inhibit reproductive functions and milk secretion ceases during renewed pregnancy. While in dairy breeds the reproductive process is accelerated, beef breeds and less-developed tropical breeds, Zebu and Zebu crosses in particular, are late maturing, generally do not exhibit oestrus while lactating, and cease lactating if pregnant again.

Sexual maturity is attained at different ages in the various species and breeds. Age at first parturition is economically important. Commonly dairy cattle calve for
Milk and Dairy Products in Human Nutrition

the first time at 24 months of age, sheep and goats at 12 months, mares at 3 years. However, unduly accelerating the maturation process by intensive feeding can have negative effects on reproductive function and longevity (Essl, 1998). Dairy cows can calve in 12-month intervals. For this to be achieved, taking into account the 9 months duration of pregnancy, cows must conceive again within 3 months after parturition. This requires rapid restoration of complete functionality of the genital tract and ovary after birth (Svennersten-Sjaunja & Olsson, 2005). Timely mating (AI in particular) is important to keep calving intervals within the desired time frame. High-producing cows have a tendency to show only weak and short oestrus symptoms. Heat detection is critical. Physical observation is time-consuming and unreliable (three times daily observation of the cows over 30 min is the recommended practice). Improvement in oestrus detection is sought with technical appliances such as registration of concentrate intake and behaviour pattern with telemetric methods, automatic detection at milking and analysis using computer models of changes in physical milk characteristics that indicate oestrus (temperature, electrical conductivity). The latter should also serve to detect early signs of udder inflammation (mastitis) (De Mol, 2000). As milk yield is at its peak at the beginning of lactation, when metabolism and all body functions are extremely challenged, malfunctions can only be avoided with the most sophisticated animal management.

In practice, the average calving interval is more than 12 months and calving rate is about 80% in most dairy herds. In general, with the strong increase in milk yield, the fertility of dairy cows has declined (Royal et al., 2000), for example the calving rate is declining at a rate of 1% per year in the UK. Some herdsmen find it appropriate to give high-yielding cows a rest period after three or four lactations by postponing rebreeding for several months. Also, there is some evidence that extending lactations to 18 months rather than 12-month cycles can be beneficial (Sorensen et al., 2008). Although hormonal treatment may have immediate effects in some cases, any long-term strategy must rely on improving nutrition and genetic disposition. While the heritability of all the traits involved with reproduction is low, it should be included in breeding programmes because of its great economic importance (Pryce et al., 1997).

In the tropics, reproductive rate is generally lower than in temperate zones. Late maturity and extended parturition intervals are typical (depending on breed and husbandry conditions). Energy, protein and vitamins (vitamin A in particular) are in short supply during the tropical dry season but minerals (phosphorus in particular) may be deficient all year round. Also, high ambient temperature directly reduces fertility of males and females (De Rensis & Scaramuzzi, 2003). In pastoralist herds and on ranches in semi-arid areas, calving rate is between 40 and 60%. However, even in tropical humid areas calving rate does not exceed 60–70% on average.

### Table 1.8. Zoonoses.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Organism</th>
<th>Prevalence</th>
<th>Morbidity/mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleeping sickness*</td>
<td>Trypanosoma rhodesiense</td>
<td>Epidemics †</td>
<td>High</td>
</tr>
<tr>
<td>Anthrax</td>
<td>Bacillus anthracis</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Bovine spongiform encephalopathy</td>
<td>Prion</td>
<td>Rare</td>
<td>Low</td>
</tr>
<tr>
<td>Brucellosis</td>
<td>Brucella spp.</td>
<td>Frequent, tropics</td>
<td>High</td>
</tr>
<tr>
<td>Food poisoning</td>
<td>Salmonella spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food poisoning</td>
<td>Campylobacter spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemorrhagic colitis</td>
<td>Escherichia coli O157</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>Leptospira spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listeriosis</td>
<td>Listeria monocytogenes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasteurellosis</td>
<td>Pasteurella multocida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-fever</td>
<td>Coxiella burnetii</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rift Valley fever</td>
<td>Rift Valley fever virus</td>
<td>Rare</td>
<td>Low</td>
</tr>
<tr>
<td>Tick-borne encephalitis</td>
<td>Tick-borne encephalitis virus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Mycobacterium bovis</td>
<td>Frequent, tropics</td>
<td>High</td>
</tr>
<tr>
<td>Zoonotic diphtheria</td>
<td>Corynebacterium ulcerans</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Human African trypanosomiasis.
†East and South Africa.

The reproductive rate of goats is high. They are precocious, bringing their first kid at 1 year of age. With a pregnancy duration of 5 months, the kidding interval of goats is usually 12 months but may be extended by the farmer. Small ruminants can easily achieve yearly lambing and kidding even under tropical conditions. The annual reproductive pattern of wild ruminants is governed by the photoperiod in the temperate zone, so that parturition and rearing are adjusted to the seasonal environmental conditions. This pattern has been lost during the domestication of cattle, but has been retained in most sheep and goat breeds so that they reproduce seasonally.

### 1.9 Rearing of Youngstock

Undisturbed growth during development is a precondition for healthy and productive adults. The natural process of nursing by the dam is of course the optimum. However, it is difficult to combine with milking, although this is done in low-production systems where milk in excess of intake by the calves may be milked. Typically in this situation, the nursling is separated from the dam during the night and the milk (secreted continuously over 24 hours and stored until withdrawal) is obtained by milking in the morning. In systems with high levels of milk production, the general practice is to separate calves from the dam early. As the secretion of the udder for about 5 days following parturition (colostrum) is not considered suitable for human nutrition, calves are often left to suckle during this period. However, as cows for milking must be accustomed to the stimulus of the milker, any previous experience with nursing may have a negative impact. The dam is not strongly attached to the young immediately after parturition and bonding develops only gradually. Allowing the calf to suckle and then weaning it after even a short suckling period is painful for both dam and nursling (Stěhulová et al., 2008). Also, after weaning the calf may not easily adjust to other methods of milk intake (bucket or nipple feeding). If separated immediately after parturition, the cow ‘forgets’ the young. Thus, not allowing any contact between dam and calf has proved to be the most practical procedure, although it may not be acceptable to all for animal welfare reasons (Flower & Weary, 2003).

Because of the high value of milk, and milk fat in particular, producers examined the opportunities to feed calves with cheaper products (FAO, 2011a). The industry came to their aid and milk replacers were developed based on skimmed milk powder. Today, almost universally (except in extensive operations in developing countries with low-producing cows which nurse their calves and are milked simultaneously), calves receive colostrum for 10 days and milk replacers afterwards but are bucket-fed all the time. However, in periods of excess milk production, as experienced during the past decennia in Europe, this practice does not make sense. When milk in excess of prescribed quota is paid below cost of production, it may be more economical to feed this milk to calves. Also, in biological/organic operations, milk replacers are not allowed (see section 1.2.2).

As mortality among age groups in dairy herds is highest in calves, these need particular attention. For hygienic reasons calves may be kept in close confinement in single boxes on bedded ground or on slatted floors during the first weeks of life. Strict sanitation is possible under these conditions, and infectious diseases, diarrhoea and lung disease in particular, which are a permanent menace under intensive management, can be controlled. With well-organised management and close attention, calf mortality in large herds (>500 cows) can even be lower than in smaller herds (USDA, 2007). However, in very small herds (up to 50 cows) mortality during the first 6 months of life increases with herd size (Gulliksen et al., 2009). Computer-controlled fully automated nursing systems for calves as well as for dairy goats in commercial herds have been adopted, for example in the USA, France and Taiwan (Earleywine et al., 2011).

### 1.10 Housing

Dairy animals are housed under a wide variety of conditions. In southern countries, on small-scale holdings for family milk supply they may just be tied under a tree or a simple roof. Animals that are grazing all year round will be kept in a night enclosure protected from adverse weather, predators and theft. Pastoralists may keep sheep or goats at night in their huts, tents or corrals. When milk is produced for marketing, facilities are required to keep the animals clean and to obtain milk under hygienic conditions. In advanced dairying, animals are housed in elaborate barns, including sufficient ventilation, water spray cooling and even air conditioning. There are several systems where a synthesis is sought between animal comfort, cleanliness, ease of animal handling and minimised workload.

In stanchion barns, animals are tied individually. Bedding may be provided and changed daily to be stored for later use as composted manure. Where straw is in short supply and animals stay indoors only overnight, the floor may be bare or covered with rubber mats. Faeces and urine are channelled into a reservoir to be handled as slurry. Feed is offered in a trough which may be separated by a grate for individual feeding. Animals may be milked in the stall or led to a milking parlour. Nowadays these barns are acceptable for animal welfare reasons only when animals are left out for grazing during the day, or for a limited winter period.

In loose housing, animals can move freely within a barn with continuous access to a feed trough and water supply.
The loafing area is without bedding and will be cleaned with (a minimum volume of) water. The whole area or part of it may be fitted with slatted floors to facilitate transport of the excretions and dirt to a reservoir. Slurry is produced. Stalls with or without bedding (straw, wood chips, sawdust, sand or recycled dried manure) or rubber mats are provided where animals can rest individually. They are milked in a milking parlour. Loose housing can be combined with milking robots and electronic devices for computer-controlled self-feeding. If natural ventilation in the barn is not sufficient, mechanical ventilation with fans may be necessary, under hot and humid conditions in particular. Loose housing prevails today, although it still is not yet universally accepted (USDA, 2007).

Ewes and most goats are kept in loose housing or in elevated barns with slatted floors. This helps to control reinfestation with internal parasites in tropical countries in particular. Droppings are collected for later use as manure, which is sometimes even sold to gardeners, for example in Taiwan (Morgan, 1996).

Although manure from straw bedding is best disposed on agricultural fields, the labour requirement is high and sufficient acreage may not be available. Accumulation of manure has become a problem in dairying systems that are not linked with agriculture. Slurry handling can be mechanised but there is a danger of environmental pollution. However, slurry can be a source of profitable biogas production to produce electricity on the farm and thereby emissions of methane can be reduced.

1.11 MILKING

Milking procedures and facilities are more extensively covered in Chapter 3. Milk is formed continuously in the secretory tissue of the udder. It accumulates in the milk ducts and to a lesser extent in the cistern. In order to be available to the suckling young or dairyman, it must be moved entirely into the cistern. (Note that not all the milk present in the udder can be extracted: a certain ‘residual’ proportion always remains, more often with milking, depending to some extent on the quality of the milking procedure, than with suckling.) This movement of milk into the cistern is facilitated by muscle-like cells surrounding the milk-secreting alveoli. They contract and squeeze out the milk under the effect of a hormone, oxytocin. This is released from the pituitary gland (hypophysis) by neural stimuli connected with nursing, i.e. tactile stimuli of the udder and teats but also behavioural stimuli connected with fostering (Svennersten-Sjaunja & Olsson, 2005). The decisive step in the evolution of domestic dairy animals was the ability to trigger this so-called milk let-down reflex purely by manipulating the udder at milking, without the presence of the calf. This is most marked in European dairy cattle and goats due to the success of genetic selection. In the extreme, milk will squirt from the udder (especially with weak sphincter muscles, which close the opening of the teat) even when the cow (or goat) is anticipating the act of milking, without any mechanical stimulation. In all other breeds and species used for milk production, the presence of the nursling is necessary to initiate milk extraction.

Milking can be by hand, which is sufficient with limited milk yield. The milk is obtained by squeezing the teat, the necessary pressure being determined by the tension of the teat sphincter. This pressure can be rather high so that milking is hard labour. Therefore, and to save labour time, milking with machines was developed and today is practised almost exclusively in developed countries. Usually, cows are milked twice daily, but in high-producing herds thrice daily milking is profitable and common today.

At the beginning of the age of technical developments, the milker would take the milking cluster to the individual cows. Nowadays the cows are made to walk by themselves into a milking parlour. Milk is either collected into a pail or fed into a pipe system that channels it directly into a tank where it is cooled prior to being collected by the dairy factory. Further improvements in milking devices were brought about by the introduction of milking robots. Cows fitted with electronic identification systems enter the milking robot stall when they feel like milking and when the system indicates that it is time for milking and concentrate feeding. The robot identifies the cow, cleans the udder, checks for quality milk from each quarter, attaches the cluster, supervises milk flow, detaches the teat cups when milk flow ends, disinfects the teat end, and finally makes the cow leave. The system provides for more flexibility in work organisation, although the time saved for milking is needed to maintain and clean the robot system (Rotz et al., 2003).

Hygiene in the milking process is important for both milk quality and udder health. It is maintained by proper cleansing of the udder and the whole milking line, including the application of disinfectants and by testing the milk physically and chemically for the absence of mastitic conditions prior to attaching the milking machine teat clusters.

1.12 MILK MARKETING

A well-organised marketing system serves the interest of both consumers (ensuring supply of safe, quality milk) and producers (ensuring market outlet at appropriate prices). In general, marketing problems are due to (FAO, 2000):

- the short shelf-life of the perishable milk produced daily;
- the cost of collection and transport;
- the varying volume produced during the course of the year;
• a risk of milk adulteration by skimming or watering in an uncontrolled collection and marketing system;
• the need for processing before its end use;
• the possibility of spreading zoonoses (e.g. brucellosis, tuberculosis).

In modern dairying systems, common practice today is that milk is channelled directly from the milking parlour into a cooling tank. It is stored at low temperature until shipped to the dairy factory, daily or even every second day. In the creamery, milk is subjected to heat treatment as soon as possible in order to inhibit (or at least delay) microbial action (see Chapter 14). Dairy factories have the potential to pollute water: while poor management results in waste loads of 3 kg BOD (biological oxygen demand, a measure of water pollution) per ton of milk, it can be reduced by good management practices to 1 kg (de Haan et al., 1997).

1.12.1 Marketing by smallholders

As has been pointed out, milk is an important source of income for smallholders in developing countries. In subsistence farming the marketing potential of dairy products can only be tapped directly by farmers situated close to the markets and who can themselves deliver the milk. However, the intake capacity of local rural markets is limited. While large farms can market milk or cheese directly in cities, most of the market-distant smallholders depend on organisations that purchase and collect the milk. Middlemen provide this service and in many developing countries still today up to 80% of milk is supplied to urban consumers via this so-called informal market, sometimes at half the ‘official’ price. However, this activity has limitations and deficiencies. Adulteration of milk (skimming and watering mainly), especially during lean periods, is a common problem. Middlemen often pass on an inadequate part of their profit to the producer and cannot purchase, or purchase only at very low prices, seasonal surplus milk. On the other hand, they often extend advance payment and act as a liaison to the marketplace. However, their intake capacity and trading area is limited to a certain perimeter around cities. Even the dairy factories prefer to collect milk close to the cities because milk collection over long distances is expensive due to road conditions in outlying areas in countries with insufficient infrastructure in particular. These dairies are unable to compete with the middlemen because of high fixed costs and expenses incurred by following government marketing regulations. In order to enable producers in outlying areas to benefit from any marketing opportunities, a well-organised milk collection system is required. This is in the interest of both the small farmers and the dairy factories who need sufficient volume to operate economically. If milk collection is expensive, dairy factories in some countries prefer to reconstitute milk with skimmed milk powder and butter oil (provided there are no import restrictions and the price is right; sometimes expensive butter oil is replaced with vegetable oil to produce ‘filled milk’). In doing so, they deprive the small milk producer of the benefit of marketing their milk. Government regulation may be necessary to prevent this (see the example of Operation Flood in section 1.12.3).

1.12.2 Milk collection

In the past, farmers would bring their small quantities to a collection centre, or trucks collected milk cans placed on the collection route. Often by the same route, skimmed milk (and whey) was brought back to the farmer who used it as animal feed (for pigs mainly). Today, dairy factories collect cooled milk with road tankers at the farm gate. In order to expand the collection radius and to lower costs, multi-tier milk collecting systems are employed in countries with deficient infrastructure. The small quantities from individual producers are collected at collection points from where it is brought to collection centres from where it is shipped to the dairy factory. Where infrastructure permits, one of the stages may be skipped (e.g. producers bringing milk directly to the collection centre or even to the creamery). With the multi-tier arrangement, the difficult and most expensive part of transport (off road) is covered by producers on foot, on donkey or horse back, on bicycles or small vehicles, and the following stage on poor dirt roads by pick-ups or small trucks. Only at the final stage do road tankers ship the milk to the dairy factory. Collection centres need a minimum amount of milk to operate economically. They are preferably located on a road (hard surface) to reduce the requirements for expensive transport. On the other hand, they should be close enough to the producer to keep distances short.

At the collection centre the milk is generally cooled (collection and cooling centre). If there is no option for cooling, only the morning milk may be collected and shipped to the dairy factory the same morning. Cooled milk is shipped to the dairy daily or every second day. There it will be pasteurised, processed and delivered to the retail trade. Frequently, collection centres operate as sales points for local consumption. Additionally, they may function as small social and commercial centres. Large dairy farms in areas with insufficient road structure ship their milk to the creamery in cans or with road tankers.

Originally, milk was used sweet fresh or boiled. Worldwide, since the beginning of modern dairy development, consumers and health authorities have been concerned about the possibility of disease transmission through milk (see section 1.7). Sanitation via heat treatment was introduced universally in the second half of the
nineteenth century. However, this puts an economic burden on small milk producers in particular. As consumers traditionally are used to boiling milk prior to consumption, the prior heat treatment seems not to be necessary in all situations. For example, Kenya recently changed dairy policies, legalising the sale of unpasteurised milk by the informal trade with economic benefits to producers (Owango et al., 1998; ILRI, 2008). In Zambia, milk is used mainly sour (coagulated) as additive to certain dishes. Dairy farmers let their milk turn sour and deliver it directly to retailers who sell it until noon (personal observation).

Because milk output varies during the course of the year, producers very early developed procedures to conserve milk. The simplest form is sour milk, which is prepared in various forms including some subject to alcoholic fermentation. Fat can be separated and conserved as butter or transformed into ghee. Cheese requires fairly sophisticated technology: soft cheese for short shelf-life (except for Feta cheese in brine, which gives it a long shelf-life) or hard cheese for longer preservation. In the dry tropics, milk is also dried for conservation.

1.12.3 Producer organisations

In order to reduce dependency on the milk trade, the implementation of producers’ associations (dairy cooperatives) for milk collection, processing and sale is essential in rural areas. It was key to dairy development in Europe at the onset of the cooperative movement in the nineteenth century. Even today most dairy farmers in the USA market their milk through cooperatives (US Government Accountability Office, 2004) and about 30% in Germany (Raiffeisen, 2012). In order to be competitive in the market, many cooperatives have developed into large dairy companies. Dairy cooperatives run a milk collection system and may sell milk to an industrial plant or run their own milk factories, taking care of processing and sales of milk. In addition, cooperatives provide services to member farmers (milk recording, training and advice, input procurement, insemination and veterinary service, credit).

Of major importance are the dairy cooperatives in developing countries because they open marketing opportunities to small farmers. An outstanding example in the recent past is Operation Flood, a large-scale project by the Indian National Dairy Development Board (NDDB, 2010) started in 1970 with financial support by the European Union, the World Food Programme and a World Bank loan. It is considered one of the most successful projects of development assistance in the era after the Second World War. Also called the ‘White Revolution’, alluding to the ‘Green Revolution’, it endeavoured to establish a country-wide supply grid with milk production based on dairy cooperatives. They started by organising milk collection, taking even the smallest quantities of milk. In order to make the expensive system operate, the dairy factories initially, while sufficient milk volume was not yet collected, reconstituted milk with skimmed milk powder and butter oil. NDDB was granted exclusive licence to import these commodities, which for the rest was prohibited. Cooperatives formed unions who ran dairy factories and feed mills. Milk was paid directly on delivery and receipts rapidly caused improvement of farmers’ living conditions. The criticism that sales would deprive the family of the milk needed for family feeding, infants in particular, was invalidated by proof that with the returns from milk sales it was possible to purchase six times more nutrients in other food (July 1979; see also section 1.2.5). A system for quality control, payment of producers, conservation, transport, milk processing and sale was established. Cooperatives developed into strong self-help organisations assisting with procurement of inputs (feed, fertiliser), credit, AI and veterinary service, extension, training and breed improvement. Economic success eventually allowed the cooperatives to extend their activities to infrastructure improvement and schooling. The Indian model was successfully copied in other countries.

1.13 Economics of Milk Production

The most important factor in the economics of intensive milk production is milk yield. Lifetime income is 17.4% higher with cows selected for high milk yield than with their average herd mates. Although the cost of production has also increased, the net result of high yield is positive (Dunklee et al., 1994a). It is often suspected that very high milk yield is genetically associated with more health problems and reproductive disorders and much research, both statistical and experimental, has been devoted to this question. Results are inconsistent, supporting the expectations of sceptics but also of those convinced about the benefits of breeding for high milk yield (Shanks et al., 1978; Fourichon et al., 2001).

The cost of producing milk depends on various cost factors, foremost feed, cow replacements (see also section 1.13.2), labour, healthcare and investments. As these factors vary greatly between countries, overall cost differs accordingly. A cost comparison for the major milk producing countries of the world is shown in Table 1.9. In the EU, higher costs are due to unfavourable weather conditions requiring housing of cows in wintertime, high labour costs, small farm and herd size, and the milk quota system (Deblitz et al., 1998a,b).

In industrialised countries there is a general tendency to produce more milk than the market can absorb, with
resulting pressure on producer price. Very small farm properties prevail in many European countries as a consequence of inheritance laws, which split the bequest equally among all the heirs. Their acreage does not provide sufficient family support except by intensive systems of production. As dairying is one of their mainstays, it is often subsidised. In Europe (and similarly in North America) with varying success attempts have been made to maintain producer prices by several market intervention measures: price support through intervention buying, import tariffs and export subsidies, and milk quotas to limit production levels (Commission of the European Communities, 2002; European Union, 2007a). However, since at least 2007, world market prices for dairy products have risen sharply (doubling or even tripling in some years), so that the phasing out of any subsidies was considered in 2011 and EU quotas will be abandoned by 2015 (European Commission, 2010).

In developing countries, unwanted effects result from promotional measures of governments, for example the lack of standards for large-scale farms or even their financial support. Policies prevail to provide milk at moderate prices to the urban population even to the detriment of rural producers (Morgan, 2009).

### 1.13.1 Productivity

The animal breeder may be interested primarily in a cow’s milk yield. Economic considerations require the determination of productivity. This is commonly expressed as production related to input factors. Depending on the individual situation, one may consider feed productivity, land productivity, labour productivity or capital productivity. However, income over feed cost is a practical indicator of economic performance. Where human food is in short supply, the conversion of nutrients may be decisive for justifying animal production and that of milk in particular. As can be seen in Table 1.10, the utilisation of nutrients that can be consumed directly by humans is best through milk production. Returns can exceed 100% because microorganisms of the digestive system synthesise protein and are digested by the ruminant host. As pointed out, milk production can be an important source of family income in developing countries. There, the return on labour may be most important as long as alternative sources of employment are not available.

### 1.13.2 Longevity and lifetime production

In most modern intensively managed dairy herds, most cows are removed at about 6 years of age having undergone no more than three to four lactations, before reaching the peak of their productive potential (Essl, 1998). Over the recent past, longevity has decreased in most European dairy cattle populations because selection was based on milk yield, mainly assessed early in life. Reasons for this are ill health (metabolic and udder diseases), foot problems and reproductive failure (Weigel, 2010). However, longevity is the most important factor influencing economics, because the cost of replacement is an important part of the overall cost. It was the second cost factor behind feed cost on California dairy farms in 2002 (US Government Accountability Office, 2004). A recent study in Germany revealed that cost per kilogram milk was as follows: labour €0.10, roughage €0.07, concentrates €0.07, replacements €0.06, respectively (Rindfleisch & Heber, 2009). Lifetime production combines yield with longevity and is probably the best indicator of sustainable production by healthy reproductive cows and thus is the best indicator of animal welfare. Unfortunately, the heritability of this trait is low and therefore it cannot easily be improved by selective breeding (Vukasinovic et al., 2001). However, a number of dairy herd associations have impressive numbers of records of 100 000 kg lifetime production that requires 10 lactations of 10 000 kg each, permanent health and undisturbed sequence of calving, which can only be achieved by

---

**Table 1.9.** Cost of milk production worldwide.

<table>
<thead>
<tr>
<th></th>
<th>US$/100 kg milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU farms with around 30 cows</td>
<td>50</td>
</tr>
<tr>
<td>EU farms with 60–75 cows</td>
<td>38</td>
</tr>
<tr>
<td>USA, Central Europe, Brazil and South Africa</td>
<td>25–30</td>
</tr>
<tr>
<td>Argentina, Uruguay, Australia and New Zealand</td>
<td>20</td>
</tr>
</tbody>
</table>

*Source: based on data from Deblitz et al. (1998a, b).*

**Table 1.10.** Returns from animal production.

<table>
<thead>
<tr>
<th></th>
<th>Returns on total energy (E) and protein (P) inputs</th>
<th>Returns on human-edible energy and protein inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E (%)</td>
<td>P (%)</td>
</tr>
<tr>
<td>Milk</td>
<td>23</td>
<td>29</td>
</tr>
<tr>
<td>Beef</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Swine</td>
<td>23</td>
<td>38</td>
</tr>
<tr>
<td>Poultry</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

*Inputs were calculated as digestible energy and protein and include costs of maintaining breeding.*

*Source: based on data from Bywater & Baldwin (1980).*
well-managed and well-bred cattle (German Genetics International, 2010). Consequently, today, so-called secondary or functional characteristics (in addition to milk yield), which are preconditions for longevity and high lifetime production, are becoming increasingly important and these include reproductive function, general health, sound feet, healthy and easily milked udders, and eager feeders (Groen et al., 1997; Gay et al., 2011). However, careful skilled management that provides a healthy comfortable environment is also essential.

1.14 CRITICISM OF MILK PRODUCTION

1.14.1 Resource use

Recently, animal husbandry has been increasingly criticised for the low efficiency of resource use (mainly land and water) compared with the production of vegetable food. One consequence is increasing reluctance to assist livestock development in countries that have difficulties in providing sufficient food for their population (Steinfeld et al., 2006). While the focus of this criticism is mainly on beef (and other meat) production, to some extent it also includes dairying but to a much less degree. Nevertheless, this critique needs to be qualified. Worldwide about 70% of agricultural land is pasture, varying greatly between countries (from over 90% to less than 5%) (FAO, 2011b), much of which is used, at least partly, for milk production. In smallholder dairy systems much use is made of agricultural by-products. In addition, fodder is grown as a winter crop between grains. These feed resources cannot be used better than for dairying. However, fodder is certainly grown as the sole crop where it competes with crops directly usable as human food. Worldwide, this area comprises about 14% of agricultural land but with great differences between countries, for example in India it is only about 4%.

In response to rising demand and better marketing opportunities, specialised intensive dairy operations are growing. They improve animal efficiency by adding grains to the feed. How much grain is fed to dairy animals is difficult to estimate but certainly a balance should be found between adequate supply of dairy products and optimal resource use, considering that the resources needed to produce animal products generally exceed those to produce agricultural food commodities for human consumption (cereals, sugar and oil plants, see also section 1.3), although milk production compares quite favourably with other lines of animal production (see Table 1.10).

1.14.2 Impact on the environment

Presently there is growing public concern about the environmental aspects of livestock farming practices including dairying (Place & Mitloehner, 2009; Croney & Anthony, 2011). As livestock farming expands, there is a tendency in the dry tropics for over-grazing and in sub-humid and humid zones for expansion into sites prone to erosion as well as invasion of rainforests (Steinfeld et al., 2006). Continued over-grazing may lead to desertification, while grazing of steep sites in sub-humid and humid zones may cause erosion. Wildlife may be endangered by outing of game and control of possible predators to protect livestock.

Livestock produce greenhouse gases (CO₂, nitrous oxide and methane). It is estimated that livestock cause 18% of greenhouse gas emission (in CO₂ equivalents) from human-related activities (Steinfeld et al., 2006) and the dairy sector including emissions from processing and transportation contributes 2.7%. It would increase to 4% if meat production associated with dairying was included. About 52% of it is methane (Gerber et al., 2010). Globally, livestock are the largest source of methane, which is produced when ruminants digest plant fibre (cellulose). Greenhouse gas emissions per kilogram of milk are estimated to be high in arid grassland systems (low milk yield and low feed digestibility), but low in temperate humid zones (mostly industrialised countries, high-producing cows). Emissions can be reduced mainly by efficient feed use, i.e. feeding highly digestible rations rather than high roughage rations (Hegarty et al., 2007; Paul et al., 2009). It has been estimated that feed supplementation can reduce methane emissions of dairy animals by 25% while increasing milk production by 35% (de Haan et al., 1997). Dairy production in the USA in 2007 caused less damage to the environment than in 1944 (between 10 and 56% of the 1944 values depending on the parameter considered) (Capper et al., 2009) as a result of improved management and technology as well as reduced resource use (feed, cropland, energy, water), waste output (manure, N, P), and greenhouse gas emissions. This would contradict the allegation of poor environmental stewardship of intensive dairying. Methane is also emitted from excreta, but properly handled manure is not environmentally harmful when applied on fields and pastures. Yet excessive numbers of animals on small acreages, as well as slurry from large operations, can pose problems and pollute groundwater. An EU directive stipulates the procedures to avoid pollution (Council of the European Communities, 1991).

Most extensive peasant livestock systems are climate friendly (Paul et al., 2009). They can be extremely efficient at enriching biodiversity and in sequestering greenhouse gases. The advantage of extensive livestock is revealed only if looked on as a system in which mainly land and agricultural resources are used that cannot be used directly as human food. There is also growing public concern about animal welfare (Keyserlingk et al., 2009). One of the main
issues is deprivation of dam and suckling young of the benefits of dam care (see section 1.9).

1.15 DAIRY DEVELOPMENT

Demand for milk increases with growth of the urban population. Furthermore, as income grows, people tend to increase consumption of higher priced livestock food. Consequently, milk production is enhanced. As can be seen in Table 1.11, worldwide total milk production over the last decade increased by 28% but per-head availability lagged behind. In food-deficit countries, it is less than one-third that in Europe. Milk is a staple food for many livestock owners who produce for self-supply and not for the market, such as smallholder farmers or pastoralists. Milk easily supplies protein and energy, which are both deficient in malnutrition in most cases. In developing countries, a sufficient supply of milk and dairy products to the needy (infants, pregnant women, elderly, diseased) should be ensured without unduly reducing the production of basic vegetable food (Pimentel, 2009). Ideally, most of the milk should come from small producers (Preston & Leng, 1987). In integrated farming systems, livestock barely displace cropping while animals fed mainly on pasture and agricultural by-products have positive effects beyond food production by contributing to soil conservation and fertility (manure) and by providing draught power (Nellemann et al., 2009).

The International Food Policy Research Institute (IFPRI) estimates the price elasticity of dairy products in low-income countries at –0.7 as compared with high-income countries at –0.3 (Braun, 2007), while indices of income elasticity of demand for milk are high in developing countries, estimated at between 1.43 and 1.26 (Delgado et al., 1999). Thus, the poor can barely afford expensive dairy products and this is aggravated by rising commodity prices. However, if governments try to make dairy products available to the urban population by keeping prices low, they thwart dairy development and furthermore curtail possibilities for rural producers to take advantage of the income-generating opportunities of milk production. Remunerative producer milk prices can act to transfer purchasing power from city to rural areas, whereas milk supply to the needy may be secured by direct subsidies.

Promotion of animal husbandry, dairying in particular, can trigger the improvement of living conditions of the rural family, with repercussions on crop yields directly, or indirectly via the opportunity to utilise revenues in cash for the purchase of inputs. Moreover, as dairying is often the domain of women, promotion of milk production can contribute to their well-being (FAO, 2004; see also Operation Flood). Furthermore, there is a sociocultural aspect in societies where dairy animals, cows specifically, play a role beyond their economic importance (sacred cows in India, camels with pastoralists).

Development programmes mainly aim at the following (Ndambi et al., 2007):

- policy formulation in support of smallholders;
- price control and appropriate administration of food aid imports;
- support of collection, processing and marketing of milk and dairy products preferably through producer associations;
- genetic improvement of dairy animals;
- improving veterinary services;
- training.

International organisations such as the World Bank, IFPRI, Food and Agriculture Organisation of the United Nations

### Table 1.11. Changes in world milk production from 1997 to 2007, total and percentage change.

<table>
<thead>
<tr>
<th></th>
<th>Million tonnes</th>
<th>kg/capita/year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1997</td>
<td>2007</td>
</tr>
<tr>
<td>Low-income food-deficit countries</td>
<td>86.4</td>
<td>135.9</td>
</tr>
<tr>
<td>World</td>
<td>257.8</td>
<td>329.8</td>
</tr>
<tr>
<td>Africa</td>
<td>17.1</td>
<td>26.9</td>
</tr>
<tr>
<td>Asia</td>
<td>94.2</td>
<td>139.5</td>
</tr>
<tr>
<td>Europe</td>
<td>68.8</td>
<td>67.8</td>
</tr>
<tr>
<td>India*</td>
<td>42.2</td>
<td>47.1</td>
</tr>
</tbody>
</table>

*Data are misleading as a plateau was reached in 1985; growth between 1975 and 1985 more than doubled to 31 million tonnes.

Source: based on data from FAO (2011b).
(FAO) and the International Livestock Research Institute (ILRI) envisage a future ‘Livestock Revolution’ with the following characteristics (Delgado et al., 1999):

- rapid worldwide increases in consumption and production of livestock products;
- a major increase in the share of developing countries in total livestock production and consumption;
- an ongoing change of livestock production from a multi-purpose activity with mostly non-tradable output to food market production;
- an increased use of meat and milk for grain in the human diet;
- a rapid rise in the use of cereal-based (animal) feeds;
- greater stress put on grazing resources along with more land-intensive production closer to cities;
- the emergence of rapid technological change in livestock production and processing in industrial systems.

These prospects certainly apply to dairying. Assisting developing countries with dairy development will improve the supply of milk and dairy products to consumers and at the same time, if well guided, improve the situation of small farmers.

REFERENCES


