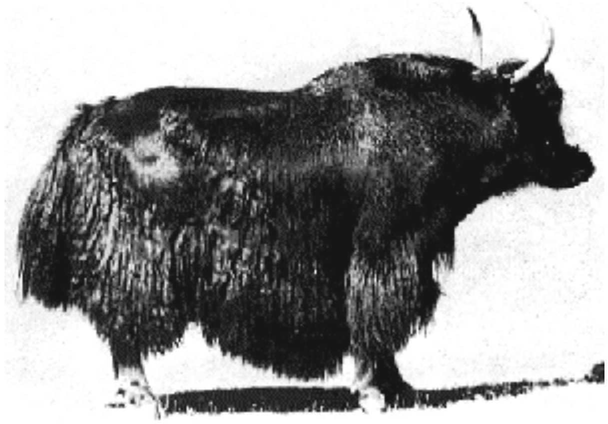


ORIGINS, DOMESTICATION AND DISTRIBUTION OF YAK

Overview

Fossil remains of the domestic yak and its wild ancestor date back to the Pleistocene period. Over the past 10 000 years or so, the yak developed on the Qinghai-Tibetan Plateau, extending over about 2.5 million sq km and often called the "roof of the world". Although this is still the centre of the yak's distribution, yak have spread northward and southward and also, albeit in relatively small numbers, to other parts of the world. Yak are usually found at elevations between 2 000 and 5 000 m (the lower elevations at the more northerly latitudes).

The wild yak may have been tamed and domesticated by the ancient Qiang people. Chinese documents from ancient times (eighth century B.C.) testify to a long-established role of the yak in the culture and life of the people. From the south to the north, the distribution of the domestic yak now extends from the southern slopes of the Himalayas to the Altai and west to east from the Pamir to the Minshan mountains. In relatively recent times the area of distribution has further extended to, for example, the Caucasus and North America. In addition, yak are found in zoos and wild animal parks in many countries.

At the present time, the total yak population is estimated to number around 14.2 million, of which 13.3 million are in Chinese territories, about 0.6 million in Mongolia and the rest in other countries, notably those bordering the Himalayas and countries of the Commonwealth of Independent States (formerly the Soviet Union). Their numbers are said to be increasing in some areas of China. In addition, hybridization of yak with cattle - most usually the local cattle of the area - is widely practised. Hybrids of yak with "improved" European breeds are also produced, though in relatively small numbers.

The wild yak population, as distinct from the domestic yak, is now very restricted in distribution. Numbers are likely to be fewer than 15 000. Although the animals are "protected", illegal hunting still represents a major problem to their survival. Wild yak are larger in size than the domestic ones. Because the two types readily interbreed, there is interest in the use of wild yak to improve the performance of the domestic type.

The yak is integrally associated with the culture, religion and social life of its herders, their families and communities. However, with outside pressures influencing the life of the people and with technical developments impinging on yak husbandry, it seems likely that the nature of yak keeping has entered a period of change.

Introduction

The yak *(Poephagus grunniens* or *Bos grunniens)* must be regarded as one of the world's most remarkable domestic animals as it thrives in conditions of extreme harshness and deprivation while providing a livelihood for people. A herbivore, the yak lives predominantly on the "roof of the world", as the Qinghai-Tibetan Plateau is often called. The Plateau itself extends over 2.5 million sq km (about 1 million square miles) and was described by Miller (1990) as the most extensive high-elevation region on earth and the best grazing lands in all of Asia. For those more familiar with the western hemisphere, Miller (1990) equated the vast size of this Plateau to the combined areas in the United States of America of Montana, Wyoming, Idaho, Utah, Nevada, Colorado, Arizona and New Mexico. From the central "core" of the yak's habitat, the species has spread to adjacent territories. These areas are, to a large extent, above the tree line where there is virtually no cropping. There is no frost-free period during any part of the year. At its high elevation, the territory overall is characterized by a harsh climate of cool moist summers, severely cold winters and grazing resources restricted by very short growing seasons. More than 13 million yak thus live and provide food, transport, shelter and fuel where few other animals will survive. About 30 million sheep and goats (Miller, 1990) - and the herdsmen's horses - co-exist with yak over large parts of the Plateau. But these are not serious competitors to the yak in much of yak territory, and they do not have the same economic importance. However, yak and sheep are, to some extent, complementary to each other in their grazing habits. In some of the alpine regions, the terrain is also treacherous. Chinese historians have argued that without the yak's capacity to live in such a hostile environment, human civilization might not have established and flourished in these remote areas.

This book traces briefly the development of this remarkable animal and then describes in some detail its characteristics and performance and its products. There is also a discussion of the more recent research and development projects that may provide a basis for improvements in yak performance and in the utilization of the rangelands. The research and development may also lead to a wider distribution for the yak and to a better utilization of yak products. Any marked changes in yak husbandry are also likely to have far-reaching consequences for the social fabric of a society of pastoralists.

Origins

Unequivocal evidence to link the modern yak to its earliest ancestors is not available. Fossil evidence suggests that yak were extensively distributed in north-eastern Eurasia in the late Tertiary period (2.5 million years ago) and that these are the forerunners of wild yak found as Pleistocene fossils in northern China, Inner Mongolia (China), eastern Siberia and northern mid-Asia and on a line roughly connecting these locations (Dyblor, 1957; Belyar, 1980; Flerow, 1980; Olsen, 1991; but see also Chapter 15, Systematics and phylogeny).

The principal area of distribution for the remaining wild yak of modern times is discussed in the section on wild yak later in this chapter. The Himalayas rose to their present elevation above 4 500 m only in the late Pleistocene epoch. Their rise obstructed the warm and damp airflow from the south and significantly changed the climate of the central area of what is now the Qinghai-Tibetan Plateau. Forest disappeared from the Plateau and was replaced by alpine meadow. Wild yak migrated from northeastern Eurasia and adapted to life on the Plateau and domestication followed.

Domestication and historical distribution

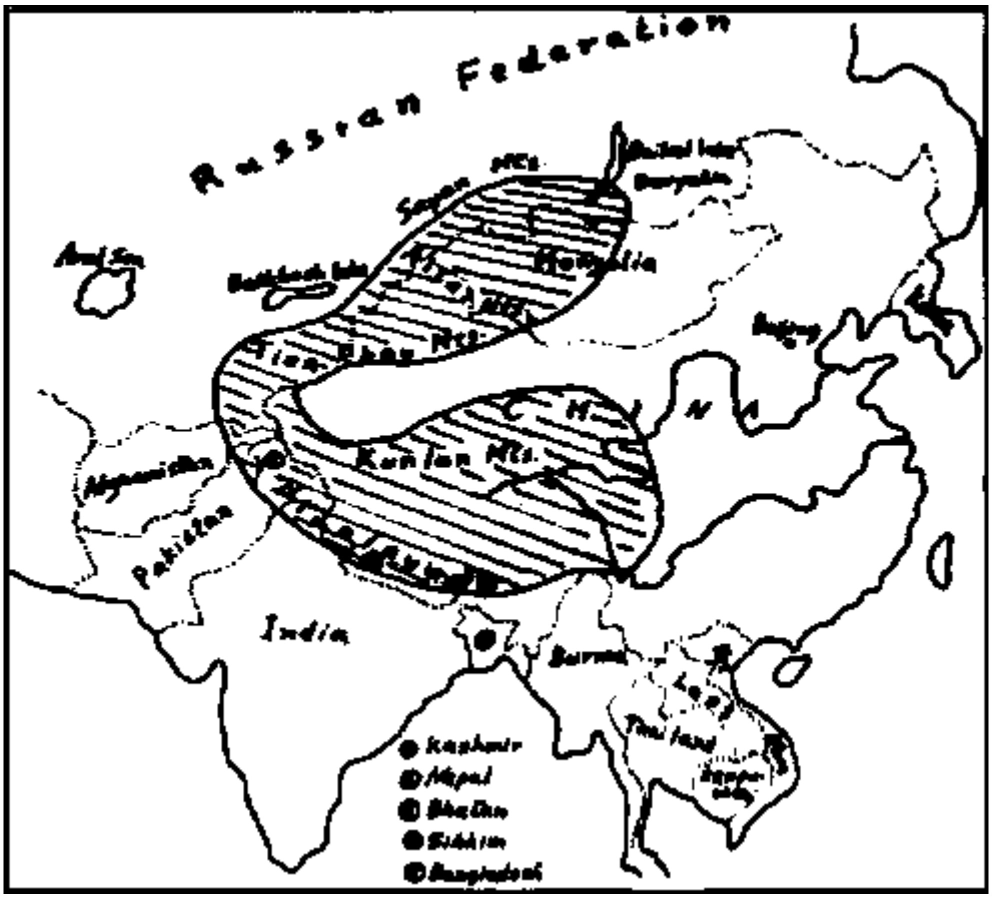
The present domestic yak is descended from wild yak, which may have been caught and tamed by ancient Qiang people in the *Changtang* (a Tibetan term meaning "the empty highland of the north"), an area that covers more than half of Tibet.

This process is thought to have begun in the late Stone Age, about 10 000 years ago, and led to the primary yak industry, beginning in the period of the Longshan Culture of the late New Stone Age (2 800 - 2 300 B.C.) (Qian Yanwen, 1979). The history of China's yak industry is thus at least 4 500 years old. Chinese historians regard the ancient Qiang people living around 30 000 years ago as the first intelligent humans. They lived and roamed the present Qinghai-Tibetan Plateau, though its average altitude then, at around 3 000 m, was lower than it is now. These people developed quite possibly the earliest animal husbandry culture of excellence in the world - the Qiang Culture. This development is of a different type from that based on agriculture in ancient Mesopotamia, widely regarded as the cradle of civilization. The outstanding achievement of the Qiang Culture was the taming of wild beasts for domestic purposes. Sheep and goats had already been tamed successfully and this led to the taming of yak, horse and other herbivores and the development of a society based on animal husbandry. Domestication of yak in particular led to progress, prosperity and economic advancement for the people because of the value of the yak as a beast of burden and its products of milk, hair, hides and meat - and the availability of its dung as a fuel in the areas above the tree line.

Yak expanded outward from that original area of domestication on the Plateau. To the east, yak migrated from the Bayan Kala mountains into the Songpan grasslands (located in what are now the Aba, Ruoergai and Hongyuan counties of Sichuan province) and into the Danba mountains. To the south, the migration went through passes in the Himalayas to the mountainous grasslands of the southern slopes of the range. To the west, yak entered Kashmir through the western Tibet grasslands. And to the north the migration took the yak over the Kunlun mountains into northern Pamir, northern and southern Tianshan and Altai.

The present-day distribution of the yak developed gradually from these migrations (see Figure 1.1).

Figure 1.1 Principal area (hatched) of the distribution of domestic yak



Nearly all the nationalities that now keep yak are thought to be related to the ancient Qiang people, including, for example, the Suchas and Tibetans. Others such as the Menba, Luoba and the Sherpa people of Nepal were separated from the original Qiang only when they entered the southern slopes of the Himalayan range. The Luoba became the Yi nationality when they migrated to the Yungui Plateau from the east. Similarly, nationalities in central Asia and the Tianshan area are related to the Qiang people, as are the Mongolian and other southern nationalities.

Many old Chinese documents illustrate these links and the associations with the yak. For example, the *Guoyu chuyu* describes events in the late Western Zhou Dynasty (ca. 841 B.C.): "... The Bapu's rhinoceros and yak cannot be destroyed ..." (Bapu was the northern part of the ancient Ba nation located in the present Daba mountains area of Sichuan province). The old text describes how yak were raised in large numbers.

A geological document, the *Shanhaijing Zhongshanjing*, dating from 400 B.C., states: "In the northeast there is a mountain called Jingshan. Its northern slope abounds with iron and the southern slopes are rich in gold. There are many yak on the mountain...." The Jingshan is at the extremity of the Daba range in what is now the Xiangyan area of Hubei province.

Many other Chinese documents dating from the fourth to the first century B.C. attest to the abundance of yak on the mountainous slopes. They also describe the migration, often forced by oppression from despotic rulers, of the Qiang people who took their yak with them. The Qiang people thus branched into what became different races living in isolation from each other. One of these was the sixth Mao Niu race - a name synonymous with one of the names for yak (Tong Pingya and Zhao Guopan, 1990).

Another branch of the Qiang people deserves particular attention because of their association with the Jiulong yak, which is now, in terms of its performance, among the most renowned native breeds of China. These people migrated to southern Kangding in what is now the Ganzi Tibetan autonomous prefecture of Sichuan province. They called themselves *muya*, meaning "yak country". The centre of this territory was in the Mula region of Yajiang county of the prefecture, the original home of the Jiulong breed. The people and therefore the area of distribution of this breed spread, as the yak industry developed, to include several other counties within Sichuan (Kangding, Jiulong, Daofu and Litang) as well as Zhongdian county of Yunnan province.

Thus, the raising of yak was a national characteristic of the ancient Qiang people. Their nomadic lifestyle has carried over into much of yak keeping to this day.

Gradually, the distribution of the yak expanded. But only in relatively modern times did it reach some of the areas where yak are now regarded as important. For example, the raising of yak in the Tianshan mountain area of the Xinjiang Uygur Autonomous Region is only about 100 years old. A century ago, 6 male and 170 female yak were taken from Tibet to Hejing county in the centre of the Tianshan mountain range and the whole of Tianshan (Yu Daxin and Qian Defang, 1983).

Present distribution

In Asia and traditional territories

Yak are found extensively on the plateau of western China in alpine and subalpine regions at altitudes from 2 000 - 5 000 m with a cold, semi-humid climate. The area, as seen in Figure 1.1, extends from the southern slopes of the Himalayas in the south to the Altai in the north and from the Pamir in the west to the Minshan mountains in the east. The centre of the yak's distribution is the Qinghai-Tibetan Plateau, which is interspersed with several mountain ranges. From the most recently available information (mostly 1997), the number of yak in Chinese territories is estimated to exceed 13 million, of which about 15 percent are hybrids with (mostly) *Bos taurus* cattle of local types. The majority of the yak, as shown in Table 1.1, are concentrated in four of that region's provinces. The rest of the world accounts for another million or so yak.

The majority of the yak in Mongolia are found in the Hangay and Hovsgol mountains and in the high altitude area of the Mongolian Altai - on the western and northern side of the country (cf. Chapter 11, part 2).

The yak in countries of the Commonwealth of Independent States (CIS, formerly the Soviet Union) are distributed in the narrow mountain area on the borders with China and Mongolia from Pamir in the west to Lake Baikal in the east. Yak were also introduced to the high alpine areas of the northern Caucasus in 1970, and reintroduced to the Yakutsk valley of Siberia (Yakutia) as recently as 1971 (Verdiev and Erin, 1981), to exploit the potential for meat production from otherwise inhospitable alpine grasslands. The yak of Nepal and Bhutan are on the southern slopes of the Himalayas while those of India are distributed in the high altitude northern provinces and in the small territory of Sikkim. Other pockets of yak populations are in alpine areas of Afghanistan and Pakistan, adjacent to the Qinghai-Tibetan Plateau. These areas of the yak distribution are dealt with in more detail in Chapter 11, part 2.

In the 1970s and 1980s, the yak was introduced to mountainous areas in northern China (but at lower altitudes of 1 500 - 1 800 m) to increase utilization of the grasslands in these cold areas. The results in Weichang county of Hebei province and in the Lingshan area of Beijing suggest a useful role for the yak there (Langjie Zeren *et al*., 1987; Zhong Guanhui *et al*., 1986).

Yak in China thus represent about 94 percent of the world's total number of yak but account for only a small proportion of the 140 million bovines in China (numbers in 1996, according to Xu Shangzhon, 1998).

According to Guo Shijan and Chen Weisheng (1996), 1.3 million yak were marketed in China annually. It was also estimated that the annual production from yak was 226 000 tonnes of meat, 13 000 tonnes of fibre and 170 000 pieces of skin (Xu Guifang and Wang Zhigang, 1998). Milk production was quoted as 1.4 million tonnes for 1989 by Li Yifang (1999) and 715 000 tonnes by Xu Guifang and Wang Zhigang (1998) for the year 1997. However, as roughly 40 percent of the meat, 60 percent of the milk and milk products and 80 percent of the fibre produced from yak are used by the herders' families for their own consumption (Guo Shijian and Chen Weisheng, 1996), all these estimates may fall well short of the actual contribution made by yak to the total economy.

Distribution outside Asia in modern times

Export of yak to parts of Europe, North America and other parts of Asia began in the mid-nineteenth century. The purpose was mostly for research and for the possible utilization of cold pastureland. Before that, Samuel Turner, a Briton, sent two yak bulls from Tibet to England in 1783. One died on the way there, and the other, after recovering from the journey, was mated to British cows. Several calves were born, but only one female survived to breed (with an Indian bull) (Turner, 1800).

In 1854, a total of 12 male and female yak were imported into France, also from Tibet. They appeared to acclimatise successfully but performed differently in different areas due to variations in feeding. They did best in the Cantal province of the central French Plateau.

Table 1.1 Distribution of yak and numbers (1997 - 2000 data for China*)

* Recent reports suggest that numbers in some areas of China may be higher than those derived from less-recent official statistics shown in the Table. Estimates with question marks attached may be less reliable than others.

Country	Province or region	Distribution at location	Number ('000)
China	Qinghai	All	3 716 (in 2000)
	Tibet	All	3 916 (in 1999)
	Sichuan	Western plateau and alpine	4 084 (in 2000)
	Gansu	area	
		Southern grasslands and	904 (in 1997)
	Xinjiang	Qilian	230 (in 1997)
	Yunnan	mountain area	50 (in 1997)
	Inner	Middle of the Tianshan	0.2 (in 2001)
	Mongolia	mountains	0.9 (in 1983)
	Hebei	Northwestern alpine area	0.1 (in 1983)
	Beijing	Helan mountain area	
Mongolia		Northern mountainous area	610
Countries of		Xishan cold mountainous area	100 (?)
CIS			20 (+40 hybrid)
Nepal			38
Bhutan			40-51 (?)
India			11
Pakistan			2 (?)
Afghanistan			2 (?)
North			
America			

Hybrids with cattle were produced in both possible ways - calves from native cows and calves from yak cows - with calves of the latter being reported as the better. However, although the yak disappeared after 1862, local stories lived on about animals at high altitudes that were strong, tolerant of rough conditions and with the tail of a horse (Boulnois, 1976). The horse-like tail, derived from the yak, led to the legend that the original crosses had been between cattle and horses. Clearly, the yak left an impression, but no descendants.

Small herds of yak are found in other parts of Europe, including Switzerland and Austria (Agir, 1997; Michael Goe, personal communication, 2002; Horst Geilhausen, personal communication, 2002). More detail is given in Chapter 11, part 3.

A number of yak were sent to Canada, first in 1909 and again in 1921 for trials, including hybridization with domestic cattle and with American bison in an attempt, later discontinued, to produce an animal capable of meat production in the harsh pastoral conditions of northern Canada. A similar project using only domestic cattle for the hybridizing, was conceived and carried out for some years in Alaska, starting with yak born in Canada (White *et al*., 1946).

Some yak were present in the late 1980s in the Polar Park of Edmonton, Alberta, Canada. Since then, the yak has expanded in numbers in Canada and the United States for commercial use in meat production. In addition, there are yak in a several zoological and wild animal parks in Europe, North America and elsewhere. More reference to these yak populations, some in environmental conditions thought to be atypical for yak, is included in Chapter 4 in relation to adaptation and in more detail in Chapter 11, part 3.

The name of the yak - a historical note

In the Tibetan language, yak is pronounced as "yag"; although in that form, it usually applies to the yak bull - with *dri* the equivalent Tibetan term for the female yak. Other languages follow this name closely. This use of the same name in numerous languages is considered unusual.

The ancient Chinese people called the animal *Ya Niu*. In the Shang dynasty (before 3 000 B.C.), yak was vividly written as , denoting the yak's large body, outstretched horns, long hair and big tail. In time, the name was reduced to a word pronounced as "ya". Later still, this was mispronounced as "mao" - and many homophones began to appear after the Qin and Han dynasties. These words referred not only to the yak but also to yak hair products (because 氂*mao* means "hair" in Chinese). Some people wrote 毛, pronounced "mao", as 犛, pronounced "li", and then called the yak *Li Niu*. The tiny alteration in the script led to a change of name. And this provides an interesting object lesson for good handwriting! A distinction between *Li* and *Mao* to denote yak was first made in the *Compendium of materia medica*, published by Li Shizhen in 1578. *Li Niu* was said to live in the mountains and denoted the wild yak, while *Mao Niu* was used to denote the domestic yak (Li Ruimin, 1986).

Present-day names, in spite of a common thread, vary for the yak from country to country and often from locality to locality within a country. The male and the female are generally known by different names and there is a plethora of different names for the hybrids of yak with other cattle. (For the sake of clarity in this book, the species of either sex will be referred to by its common name of "yak" and the sexes will be distinguished by the prefix "male" and "female", but with an occasional use of "bull", "steer" [castrated male] and "cow").

Some observations on the wild yak

Before the wild yak became known as *Li*, it was called *Zhong* in the Tibetan language and *Zuo* by the ancient Chinese in central China.

Li Shizhen in his *Compendium of materia medica* of 1578, said: "In the southwestern area around yak country, *Li Niu* (the wild yak) lives in the high mountains. Its appearance, hair colour and tail are the same as those of the domestic yak, but its body is larger." In 1875, N.M. Przewalski, named the wild yak *Bos mutus Prze*, in the belief that the wild yak did not make a sound or "cry". In fact, although the wild yak does not normally cry, it will let out squeaks and cries during oestrus and the breeding season and if it meets other wild beasts, just as does the domestic yak.

According to Miller and Steane (1996), wild yak once numbered in the millions in the central and eastern border areas of the Qinghai-Tibetan Plateau. Herds of them also existed on the cold pastures of western Sichuan province up to the middle of the twentieth century. Male wild yak could be seen mingling and mating with herds of female domestic yak. A few individuals with hair colour characteristics of wild yak can be seen in domestic herds to the present day - the principal visual difference being grey-white hairs, which are normally absent in the domestic yak, found around the mouth. The domestic yak that do have such grey-white hairs are those that have had, at some stage, an infusion of wild yak blood. This is particularly found among the Plateau breed of yak in Qinghai.

Excessive hunting of wild yak for food drove them from the plateau areas into mountainous areas at even higher altitudes, above 4 500 m and right to the tops of the mountains at 6 000 m. By the 1970s, wild yak were thought to be on the verge of extinction. Some survived in China's Kunlun mountains and due to protective measures by the Chinese Government, some wild herds are reported to have reappeared at elevations between 4 000 and 4 500 m. Schaller (1998) gives an authoritative account of the distribution and herd dynamics of wild yak. He reports finding few animals, except in the Changtang reserve, in the course of extensive visits to areas of the wild yak's present and former range. Schaller's estimate of likely total numbers is around 15 000. However, in view of improved access to much of the territory by road and continuing reports of illegal hunting, survival of the wild yak does not seem assured.

The wild yak is large in body and strong (Figure 1.2). Thick, long hair covers the whole body. The colour of the hair is jet brown or jet black. This is virtually the exclusive colour, but Schaller (1998) reported a golden brown mutation among wild yak seen in the Aru Basin of northwestern Tibet. A colour line down the back of the body and behind the withers is silver grey and there are grey-white hairs around the muzzle. (As referred to earlier, the latter feature is found only in domestic yak that have some wild yak blood.)

Figure 1.2 Wild yak bull of the Kunlun type (Photo courtesy of Lu Zhonglin)

The horns are round and very thick, 15 - 20 cm in diameter. (Some herdsmen used these horns as milking vessels and this can still be found in some remote areas of the country.) The horn arch of the wild yak is open (Figure 1.3), and the head shape has a fierce appearance.

Figure 1.3 Horn arch and part of a wild yak skull (undated) discovered in the middle reaches of the Heihe River in Ruoergai county, Sichuan province

The skull illustrated in Figure 1.3 is the largest of several skulls found in the middle and lower reaches of the Heihe Riverof Ruoergai county, Sichuan province and presumed to be ancient remains of wild yak. Measurements of the skull are as follows:

Forehead width - highest	34 cm
Forehead width - lowest	28 cm
Distance between base of horns	27 cm
Circumference of base of horns	44 cm
Horn length	99 cm
Largest distance between horns	146 cm
Distance between tips of horns	126 cm

On the basis of these measurements, it was estimated that this yak had been 170 cm high at its withers, had a body length (pin bone to shoulder) of 190 cm, a heart girth of 250 cm and weighed approximately 950 kg, which is 1.5 times the average for domestic yak bulls in the same area (Cai Li, 1989). Schaller (1998) quotes figures based on a number of published studies suggesting a shoulder height for adult wild yak bulls of 175 - 203 cm and of 137-156 cm for adult females. A total body length is given as 358 - 381 cm for bulls. Wild yak bulls are said to be about 35 percent heavier than the cows. The length of 53 horns of wild yak bulls found in the Changtang reserve is reported by Schaller (1998) to have averaged 75.7 ± 10.7 cm along the outside curve.

Wild yak prefer to live in herds of tens or even hundreds of animals. The wild yak has a very acute sense of smell, is highly alert and timid; it tries to escape immediately on sensing or seeing people or other animals. Wild yak stampede readily, but if angered or cornered they are fierce and will attack an intruder. Wild yak dislike heat but are highly tolerant of cold and starvation. Wild yak bulls often wander off individually during the non-breeding season to hill areas away from the high mountains. Such males are known to attack people on remote roads.

In times when wild yak were more prevalent, they were known to come down from the mountains to mate with female domestic yak during the breeding season. The first crossbred generation (F1[1]) between the wild and the domestic yak was similar in appearance to the wild yak and had a larger body and fiercer temper than the typical domestic yak. The crosses are difficult to manage, but the herdsmen like them because of their apparently better growth and development compared to pure domestic yak. They are also liked because the crossbred males are perceived as protecting the herd better than their domestic counterparts. There is now an attempt, organized by provincial yak breeding centres, to exploit the potential benefits of such crossbreeding through the use of semen from wild yak bulls to inseminate domestic yak cows. Some observations on the body size and performance of such crosses are included in Chapter 3.

Feral yak

Recently, 250 - 300 feral yak were discovered in the Helan mountains of Inner Mongolia at an elevation of 2 500 - 3 000 m (Han Jianlin personal communication, 2002). These animals are thought to be the offspring of yak that lived about 200 years ago that were used at that time by lamas to transport Tibetan religious books from Qinghai to Gansu. The herd contains a high proportion of white animals, which suggests they may be related to Tianzhu White yak. Currently, there is no confirmation of this. Some of the oldest residents in the region contend that these yak are only about half the size that they were 50 years ago. This is attributed, with agreement from local technical staff, to inbreeding in the herd. Local farmers also believe the lack of salt in the area may have contributed to what is described as the degeneration of the animals over the years. These yak are said to have shorter and thinner coats than what is normal for other yak and this is attributed to the fact that the area is warmer than typical for yak-producing areas. It would be useful to have more detailed studies of these animals to determine their kinship to other yak and possibly their inbreeding status and to have some record of their performance, reproduction and survival rates.

Yak in the culture of the people

As noted earlier, the yak has a long documented history stretching into ancient times. As the people who kept them migrated, they took their yak with them into wider territory. It is important to stress how closely involved the yak has been, and is, with the culture, religion and social life of the pastoral people of the cold, high-mountainous regions of Asia - at least among those people who can trace their history of yak keeping back over the centuries. This will be given more detailed consideration in Chapter 12 (see also Miller, 2002). The traditions and traditional knowledge of yak keeping provide a suitable counterbalance for the scientific and technological considerations - the main concerns in this book. It is possible, of course, that the cultural and social context of yak herding may diminish in the future in the face of the introduction of market-driven economics and of improved transport and communication. It is also possible that the spread, however slow, of modern concepts of feeding, management and breeding, and the pressures on yak husbandry from those proffering such technological advice, might further erode the force of traditional values. In some areas, such as Nepal, social change in relation to its yak economy, as documented by, for example, Bishop (1989), has led to a great reduction in yak numbers. It would be a pity if the natural resources of the vast territories now purposefully exploited by the yak were to become less productive or deserted through insensitive management of change.

The yak takes its place alongside other animals, both real and mythical, in the history, legends and mythology of the Tibetan region and neighbouring territories, as illustrated with examples by Cayla (1976). The yak and yak emblems are closely associated with many aspects of religious practice of Tibetan Buddhism and depicted widely in temple art, as described succinctly by Olsen (1990). The use of the yak as provider of components for local medicines is but one aspect of their near-mystical importance. Meyer (1976) described some of these medicines and remedies associated with the yak.

As discussed in more detail in Chapter 12, religion, ceremony, social customs and attitudes to wealth and its symbols are all intertwined with each other in the life of the people and with the integral role of the yak in all aspects of that life. This intertwining has counterparts among nomadic people of Africa but is rarely applicable to animal husbandry in the western part of the world. It is important to bear these points in mind, lest it be assumed that knowledge of the reproductive and productive attributes of the yak and of modern management practices are all that is required to bring about "improvements" in the economy of yak keeping.

The spread of knowledge of the yak outside its "native" area

The relative isolation of both wild and domesticated yak in the mountainous regions of central Asia, around the Qinghai-Tibetan Plateau, is illustrated by the dearth of mention of the yak in the West until relatively modern times. If early travellers to the East had attempted to export yak, they might have been frustrated by a reputedly poor tolerance of the yak to prolonged exposure to heat at lower altitudes - particularly if this involved a relatively rapid transition from cold to hot areas. Although, as already mentioned, yak now exist in zoos and wild animal parks in many parts of the world and commercially in North America. This suggests that the degree of tolerance of the yak to heat and its adaptability to different environments may be better than traditionally thought and that this subject requires reappraisal (see Chapter 11, part 3).

Lydekker (1912) asserted that yak were known by repute in western Europe in the classical Grecian times and given the name of *poiphogoi*, or "eaters of poa grass", because they were said to feed exclusively on grass. Also, Zeuner (1963) in his *A history of domesticated animals* provided two early references to yak. The first of these dates to the latter part of the first century A.D. when Martial (a Roman poet) alluded to the use, by the ladies of Rome, of the tail of some kind of ox (*Muscarium bubulus*) as a fly-whisk, or clothes brush. Zeuner deduced that the tail was that of the yak and goes on to point out that this, in turn, suggests that overland trading routes to the East must have been fully open then. (The yak-tail fly-whisk has been well-known in India for centuries). Zeuner further referred to accounts of the thirteenth-century travels of Marco Polo, who clearly exaggerated the size of the yak when equating it to an elephant.

Boulnois (1976) provided a much fuller background to the knowledge of the yak made available by Western travellers in early times, especially from the seventeenth century onwards.

It is therefore apparent that factual information on the yak, as distinct from anecdotes, came to Europe rather late, compared to China, as seen from the many references in ancient Chinese literature. Perhaps the first Western account was by Samuel Turner, who was sufficiently impressed by the yak to send two to Europe. His book, *An account of an embassy to the Court of the Teshoo Lama in Tibet*, was published in 1800 and republished in 1971; in it he vividly described the characteristics of the yak and its environs.

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ORIGINS, DOMESTICATION AND DISTRIBUTION OF YAK

Overview

Fossil remains of the domestic yak and its wild ancestor date back to the Pleistocene period. Over the past 10 000 years or so, the yak developed on the Qinghai-Tibetan Plateau, extending over about 2.5 million sq km and often called the "roof of the world". Although this is still the centre of the yak's distribution, yak have spread northward and southward and also, albeit in relatively small numbers, to other parts of the world. Yak are usually found at elevations between 2 000 and 5 000 m (the lower elevations at the more northerly latitudes).

The wild yak may have been tamed and domesticated by the ancient Qiang people. Chinese documents from ancient times (eighth century B.C.) testify to a long-established role of the yak in the culture and life of the people. From the south to the north, the distribution of the domestic yak now extends from the southern slopes of the Himalayas to the Altai and west to east from the Pamir to the Minshan mountains. In relatively recent times the area of distribution has further extended to, for example, the Caucasus and North America. In addition, yak are found in zoos and wild animal parks in many countries.

At the present time, the total yak population is estimated to number around 14.2 million, of which 13.3 million are in Chinese territories, about 0.6 million in Mongolia and the rest in other countries, notably those bordering the Himalayas and countries of the Commonwealth of Independent States (formerly the Soviet Union). Their numbers are said to be increasing in some areas of China. In addition, hybridization of yak with cattle - most usually the local cattle of the area - is widely practised. Hybrids of yak with "improved" European breeds are also produced, though in relatively small numbers.

The wild yak population, as distinct from the domestic yak, is now very restricted in distribution. Numbers are likely to be fewer than 15 000. Although the animals are "protected", illegal hunting still represents a major problem to their survival. Wild yak are larger in size than the domestic ones. Because the two types readily interbreed, there is interest in the use of wild yak to improve the performance of the domestic type.

The yak is integrally associated with the culture, religion and social life of its herders, their families and communities. However, with outside pressures influencing the life of the people and with technical developments impinging on yak husbandry, it seems likely that the nature of yak keeping has entered a period of change.

Some observations on the wild yak

Before the wild yak became known as *Li*, it was called *Zhong* in the Tibetan language and *Zuo* by the ancient Chinese in central China.

Li Shizhen in his *Compendium of materia medica* of 1578, said: "In the southwestern area around yak country, *Li Niu* (the wild yak) lives in the high mountains. Its appearance, hair colour and tail are the same as those of the domestic yak, but its body is larger." In 1875, N.M. Przewalski, named the wild yak *Bos mutus Prze*, in the belief that the wild yak did not make a sound or "cry". In fact, although the wild yak does not normally cry, it will let out squeaks and cries during oestrus and the breeding season and if it meets other wild beasts, just as does the domestic yak.

According to Miller and Steane (1996), wild yak once numbered in the millions in the central and eastern border areas of the Qinghai-Tibetan Plateau. Herds of them also existed on the cold pastures of western Sichuan province up to the middle of the twentieth century. Male wild yak could be seen mingling and mating with herds of female domestic yak. A few individuals with hair colour characteristics of wild yak can be seen in domestic herds to the present day - the principal visual difference being grey-white hairs, which are normally absent in the domestic yak, found around the mouth. The domestic yak that do have such grey-white hairs are those that have had, at some stage, an infusion of wild yak blood. This is particularly found among the Plateau breed of yak in Qinghai.

Excessive hunting of wild yak for food drove them from the plateau areas into mountainous areas at even higher altitudes, above 4 500 m and right to the tops of the mountains at 6 000 m. By the 1970s, wild yak were thought to be on the verge of extinction. Some survived in China's Kunlun mountains and due to protective measures by the Chinese Government, some wild herds are reported to have reappeared at elevations between 4 000 and 4 500 m. Schaller (1998) gives an authoritative account of the distribution and herd dynamics of wild yak. He reports finding few animals, except in the Changtang reserve, in the course of extensive visits to areas of the wild yak's present and former range. Schaller's estimate of likely total numbers is around 15 000. However, in view of improved access to much of the territory by road and continuing reports of illegal hunting, survival of the wild yak does not seem assured.

The wild yak is large in body and strong (Figure 1.2). Thick, long hair covers the whole body. The colour of the hair is jet brown or jet black. This is virtually the exclusive colour, but Schaller (1998) reported a golden brown mutation among wild yak seen in the Aru Basin of northwestern Tibet. A colour line down the back of the body and behind the withers is silver grey and there are grey-white hairs around the muzzle. (As referred to earlier, the latter feature is found only in domestic yak that have some wild yak blood.)

Figure 1.2 Wild yak bull of the Kunlun type (Photo courtesy of Lu Zhonglin)

The horns are round and very thick, 15 - 20 cm in diameter. (Some herdsmen used these horns as milking vessels and this can still be found in some remote areas of the country.) The horn arch of the wild yak is open (Figure 1.3), and the head shape has a fierce appearance.

Figure 1.3 Horn arch and part of a wild yak skull (undated) discovered in the middle reaches of the Heihe River in Ruoergai county, Sichuan province

The skull illustrated in Figure 1.3 is the largest of several skulls found in the middle and lower reaches of the Heihe Riverof Ruoergai county, Sichuan province and presumed to be ancient remains of wild yak. Measurements of the skull are as follows:

Forehead width - highest	34 cm
Forehead width - lowest	28 cm
Distance between base of horns	27 cm

Circumference of base of horns	44 cm
Horn length	99 cm
Largest distance between horns	146 cm
Distance between tips of horns	126 cm

On the basis of these measurements, it was estimated that this yak had been 170 cm high at its withers, had a body length (pin bone to shoulder) of 190 cm, a heart girth of 250 cm and weighed approximately 950 kg, which is 1.5 times the average for domestic yak bulls in the same area (Cai Li, 1989). Schaller (1998) quotes figures based on a number of published studies suggesting a shoulder height for adult wild yak bulls of 175 - 203 cm and of 137-156 cm for adult females. A total body length is given as 358 - 381 cm for bulls. Wild yak bulls are said to be about 35 percent heavier than the cows. The length of 53 horns of wild yak bulls found in the Changtang reserve is reported by Schaller (1998) to have averaged 75.7 ± 10.7 cm along the outside curve.

Wild yak prefer to live in herds of tens or even hundreds of animals. The wild yak has a very acute sense of smell, is highly alert and timid; it tries to escape immediately on sensing or seeing people or other animals. Wild yak stampede readily, but if angered or cornered they are fierce and will attack an intruder. Wild yak dislike heat but are highly tolerant of cold and starvation. Wild yak bulls often wander off individually during the non-breeding season to hill areas away from the high mountains. Such males are known to attack people on remote roads.

In times when wild yak were more prevalent, they were known to come down from the mountains to mate with female domestic yak during the breeding season. The first crossbred generation (F1[1]) between the wild and the domestic yak was similar in appearance to the wild yak and had a larger body and fiercer temper than the typical domestic yak. The crosses are difficult to manage, but the herdsmen like them because of their apparently better growth and development compared to pure domestic yak. They are also liked because the crossbred males are perceived as protecting the herd better than their domestic counterparts. There is now an attempt, organized by provincial yak breeding centres, to exploit the potential benefits of such crossbreeding through the use of semen from wild yak bulls to inseminate domestic yak cows. Some observations on the body size and performance of such crosses are included in Chapter 3.

Feral yak

Recently, 250 - 300 feral yak were discovered in the Helan mountains of Inner Mongolia at an elevation of 2 500 - 3 000 m (Han Jianlin personal communication, 2002). These animals are thought to be the offspring of yak that lived about 200 years ago that were used at that time by lamas to transport Tibetan religious books from Qinghai to Gansu. The herd contains a high proportion of white animals, which suggests they may be related to Tianzhu White yak. Currently, there is no confirmation of this. Some of the oldest residents in the region contend that these yak are only about half the size that they were 50 years ago. This is attributed, with agreement from local technical staff, to inbreeding in the herd. Local farmers also believe the lack of salt in the area may have contributed to what is described as the degeneration of the animals over the years. These yak are said to have shorter and thinner coats than what is normal for other yak and this is attributed to the fact that the area is warmer than typical for yak-producing areas. It would be useful to have more detailed studies of these animals to determine their kinship to other yak and possibly their inbreeding status and to have some record of their performance, reproduction and survival rates.

Yak in the culture of the people

As noted earlier, the yak has a long documented history stretching into ancient times. As the people who kept them migrated, they took their yak with them into wider territory. It is important to stress how closely involved the yak has been, and is, with the culture, religion and social life of the pastoral people of the cold, high-mountainous regions of Asia - at least among those people who can trace their history of yak keeping back over the centuries. This will be given more detailed consideration in Chapter 12 (see also Miller, 2002). The traditions and traditional knowledge of yak keeping provide a suitable counterbalance for the scientific and technological considerations - the main concerns in this book. It is possible, of course, that the cultural and social context of yak herding may diminish in the future in the face of the introduction of market-driven economics and of improved transport and communication. It is also possible that the spread, however slow, of modern concepts of feeding, management and breeding, and the pressures on yak husbandry from those proffering such technological advice, might further erode the force of traditional values. In some areas, such as Nepal, social change in relation to its yak economy, as documented by, for example, Bishop (1989), has led to a great reduction in yak numbers. It would be a pity if the natural resources of the vast territories now purposefully exploited by the yak were to become less productive or deserted through insensitive management of change.

The yak takes its place alongside other animals, both real and mythical, in the history, legends and mythology of the Tibetan region and neighbouring territories, as illustrated with examples by Cayla (1976). The yak and yak emblems are closely associated with many aspects of religious practice of Tibetan Buddhism and depicted widely in temple art, as described succinctly by Olsen (1990). The use of the yak as provider of components for local medicines is but one aspect of their near-mystical importance. Meyer (1976) described some of these medicines and remedies associated with the yak.

As discussed in more detail in Chapter 12, religion, ceremony, social customs and attitudes to wealth and its symbols are all intertwined with each other in the life of the people and with the integral role of the yak in all aspects of that life. This intertwining has counterparts among nomadic people of Africa but is rarely applicable to animal husbandry in the western part of the world. It is important to bear these points in mind, lest it be assumed that knowledge of the reproductive and productive attributes of the yak and of modern management practices are all that is required to bring about "improvements" in the economy of yak keeping.

The spread of knowledge of the yak outside its "native" area

The relative isolation of both wild and domesticated yak in the mountainous regions of central Asia, around the Qinghai-Tibetan Plateau, is illustrated by the dearth of mention of the yak in the West until relatively modern times. If early travellers to the East had attempted to export yak, they might have been frustrated by a reputedly poor tolerance of the yak to prolonged exposure to heat at lower altitudes - particularly if this involved a relatively rapid transition from cold to hot areas. Although, as already mentioned, yak now exist in zoos and wild animal parks in many parts of the world and commercially in North America. This suggests that the degree of tolerance of the yak to heat and its adaptability to different environments may be better than traditionally thought and that this subject requires reappraisal (see Chapter 11, part 3).

Lydekker (1912) asserted that yak were known by repute in western Europe in the classical Grecian times and given the name of *poiphogoi*, or "eaters of poa grass", because they were said to feed exclusively on grass. Also, Zeuner (1963) in his *A history of domesticated animals* provided two early references to yak. The first of these dates to the latter part of the first century A.D. when Martial (a Roman poet) alluded to the use, by the ladies of Rome, of the tail of some kind of ox (*Muscarium bubulus*) as a fly-whisk, or clothes brush. Zeuner deduced that the tail was that of the yak and goes on to point out that this, in turn, suggests that overland trading routes to the East must have been fully open then. (The yak-tail fly-whisk has been well-known in India for centuries). Zeuner further referred to accounts of the thirteenth-century travels of Marco Polo, who clearly exaggerated the size of the yak when equating it to an elephant.

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As would be expected, growth and development of the yak is highly influenced by the seasons, which, along with the location, largely determine pasture growth and hence the feed supply. Age, sex, type or breed of yak and herd management are among the other main causes of variation.

Body weight

Birth weight

In general, birth weight is low, ranging from 10 kg to 16 kg and representing about 3 to 7 percent of adult weight. The relatively low birth weight is a consequence of a relatively short gestation length (see Chapter 5) and the fact that in mid- and late pregnancy the yak, typically, has to exist on ground that is frozen and covered with ice and snow. Also, the yak does not normally have the benefit of supplementary feeding. For these nutritional reasons, the physical condition of the female yak is at its lowest in late pregnancy thus leading to nutrient deficiency for the foetus at the very time when the foetus is at its most demanding. The consequence is relatively poor foetal development. Table 6.1 provides some results from different sources and breeds - showing the Jiulong yak of Sichuan province with the highest absolute birth weights and the "Pengbo" yak in Tibet with the lowest.

Table 6.1 Birth weights of male and female yak of different breeds at different locations in China.

Province	**Breed or local yak***	**Male**			**Female**			**Source (first author *et al.*)**
		No.	**Weight (kg)**	**Proportion of adult weight (%)*****	**No.**	**Weight (kg)**	**Proportion of adult weight (%)*****	
Sichuan	Jiulong	27	15.9	2.9	24	15.5	5.8	Cai Li *et al.*, 1980a
Sichuan	Maiwa	77	13.4	3.2	71	11.9	6.5	Chen Xiafei *et al.*, 1981
Sichuan	Maiwa	35	14.7	3.6	60	13.0	5.8	Longri Breeding Farm, 1993
Yunnan	Zhongdian	11	14.5		14	12.8		Duan Zhongxuan and Huang Fengying, 1982
Gansu	Tianzhu White	25	12.7		24	10.9		Research Co-operative Group, 1980 - 1987
Gansu	Maqu#	45	14.6		46	13.5		Zhao Bingyao *et al.*, 1984
Qinghai	Plateau	11	13.4		11	13.1		Lei Huanzhang *et al.,* 1983
Qinghai	Datong#	52	13.2		59	11.8		NW China Animal

								Science Institute, 1960
Qinghai	Plateau (?)	37	13.2	3.1	37	11.8	3.5	Song Jianxin *et al.*, 1982
Qinghai	Guoluo	16	11.7		24	11.8		Li Quan *et al.*, 2000a
Tibet	Alpine	46	13.7		32	12.8		Research Co-operative Group 1980 - 1987
Tibet	Pengbo#**	(63)	(10.5)					Ma Zongxiang and Dou Yaozong, 1981
Xinjiang	Bazhou	8	15.8		17	14.3		Agri. Exploit. Acad. Of Xinjiang, 1984

* Jiulong, Maiwa, Tianzhu White and Alpine are "listed" Chinese yak breeds. ** Number and average of male and female yak calves combined. *** Birth weight as a proportion of adult weight. # Yak name denotes locality or farm ? breed or type assumed.

Although breed differences in birth weight may exist, it is not possible, as already mentioned, to differentiate between the effects of breed and those of location. Female calves are, on average, about 1 kg lighter at birth than the males.

Supplementary feeding of dam over winter. An experiment conducted at the Longri Breeding Farm examined the effect of two methods of supplementary feeding of the dams during pregnancy. (This experiment, conducted by the then Southwest Nationalities College [now University] with support from UNDP/FAO was described in Chapter 5 in the section on calf survival). Table 6.2 shows the effects of supplementary feeding of dams in winter or early spring on birth weight and the subsequent daily gain of the calves.

As seen in Table 6.2 the effects of supplementary feeding of the dams were small but positive both on birth weight and daily weight gain and may have reached statistical significance, according to the report of Wen Yongli *et al.* (1993). A feeding experiment conducted by Dong Shikui *et al.* (personal communication, 2000) on Tianzhu White yak showed that the birth weight was improved by nearly a third and weight gain of calves was doubled when the dams were supplemented with urea multinutritional molasses blocks (UMMB) from the start of December 1998 to the end of April 1999. In both experiments, the improved weight gain was likely to be attributable to the advantages of a higher birth weight and a slightly better milk yield of the supplemented dams (see also Tables 6.6 and 6.7 for the effects of rearing on calf growth). Any advantage in terms of body weight must also be viewed in conjunction with the small but positive effect of the winter feed supplementation on the number of calves born and reared (see Table 5.10). Further information on the effects of supplementary feeding is presented in Chapter 14.

Table 6.2 Birth weights and weight gain to 90 days of age of Maiwa yak calves from three groups of dams Least squares means and standard deviations [Source: Wen Yongli *et al*. 1993]

Year	Treatment group	No. calves	Birth weight (kg)		No. calves	Daily weight gain (g/day) (90 days)	
			Mean	SD		Mean	SD
1989/90	Hay	36	16.2	2.2	32	300	83
	Paddock grass	41	16.0	2.2	36	298	54
	Control	81	14.5	2.5	66	279	51
1990/91	Hay	35	18.1	2.4	30	316	88
	Control	98	15.6	3.7	98	295	57

a) fed hay from mid-December to end of April, b) allowed access to conserved grass paddocks from 1 April for 45 days and c) unsupplemented, control.

Parity and age of cow. Both parity and age of yak dam have effects on the birth weight of their calves, as shown in Table 6.3 and as widely reported in studies on ordinary cattle elsewhere. Data are again taken from the Longri experiment involving trials of the effects of supplementary feeding during pregnancy. (Because supplementary feeding of the dams has affected calf weights in this experiment, the overall mean birth weight of all the calves is also somewhat higher than it would be without the inclusion of the feed-supplemented groups [the least squares mean for each treatment group were shown in Table 6.2]. Therefore, effects of parity and age of dam, shown in Table 6.3, are presented as deviations from the overall fitted mean of the data.)

Table 6.3 Effects of parity and of age of yak cow on the birth weight of her calf, shown as deviations from the least squares fitted mean [Source: Chen Zhihua *et al*., 1994]

Parity of dam	No. of cows	Deviation of birth weight (kg)	Age of dam (years)	No. of cows	Deviation of birth weight (kg)
1	37	-0.02	4	33	-0.52
2	27	-0.34	5	9	-0.24

3	26	-0.26	6	3	-0.23
4	28	-0.90	7	20	0.62
5	20	0.81	8	21	0.25
6	18	0.71	9	32	0.54
			10	38	-0.42

It is apparent from the results of Chen Zhihua *et al.* (1994) shown in Table 6.3 that calves born in early parities are lighter in weight than those born to later-parity dams. However, unlike most results from "improved" cattle breeds, calves born to first-parity dams were not at great disadvantage. Similarly, the effects of age (as distinct from parity) show that young yak cows had calves slightly lighter in weight than those born to older cows - though the oldest age group started to show, as might be expected, a decline in the birth weight of its calves. The variation is not large (though statistically significant) and there are some estimates that disrupt a steady trend (e.g. the estimate of a relatively large negative effect of fourth parity). It is not clear, however, how accurately an analysis such as this can estimate the effects of parity and age of the dam when both factors are included at the same time, as the two are partially confounded. Some aberrant values are not surprising.

Body weight of cow. According to Zhang Rongchang's observations in Tianzhu White yak (personal communication, 2000), calf birth weight is highly related to the mother's body weight. In his study, yak dams weighing less than 200 kg produced young of around 15.2 kg at birth (n=27), while newborn from yak dams weighing 201 - 230 kg and those weighing above 231 kg had offspring of about 16.4 kg (n=41) and 16.9 kg (22), respectively.

Other effects on birth weight and growth

Month of calving. Most calves are born from April to July, with May the peak month. Birth weight varies to some extent with month of calving (Table 6.4), as shown by the experiment at the Longri Breeding Farm in Sichuan, mentioned previously. As in respect of Table 6.3, and for the same reason, the results in Table 6.4 are presented as deviations from the overall least squares mean.

Apart from the unexpectedly low birth weight of calves born in the first half of June, there is a steady increase in birth weight from the middle of April to the middle of July, with all birth weights after mid-June above average and those of calves born before that below average. The variation in birth weight attributable to date of birth (as defined) was shown by Chen Zhihua *et al*. (1994) to be statistically highly significant ($P<0.01$).

Variation in birth weight with month of calving was also noted by Cai Li in F1 (*Pian Niu*) calves (hybrids of yak and cattle) born at Xiangdong Yak Farm in Ruoergai county of Sichuan. Average birth weight rose from 21.7 kg, for calves born in April, to 24.3 kg, for those born in June.

Table 6.4 Effect of date of calving on birth weight shown as deviations from the least squares fitted mean (cf. Table 6.2). [Source: Chen Zhihua *et al*., 1994]

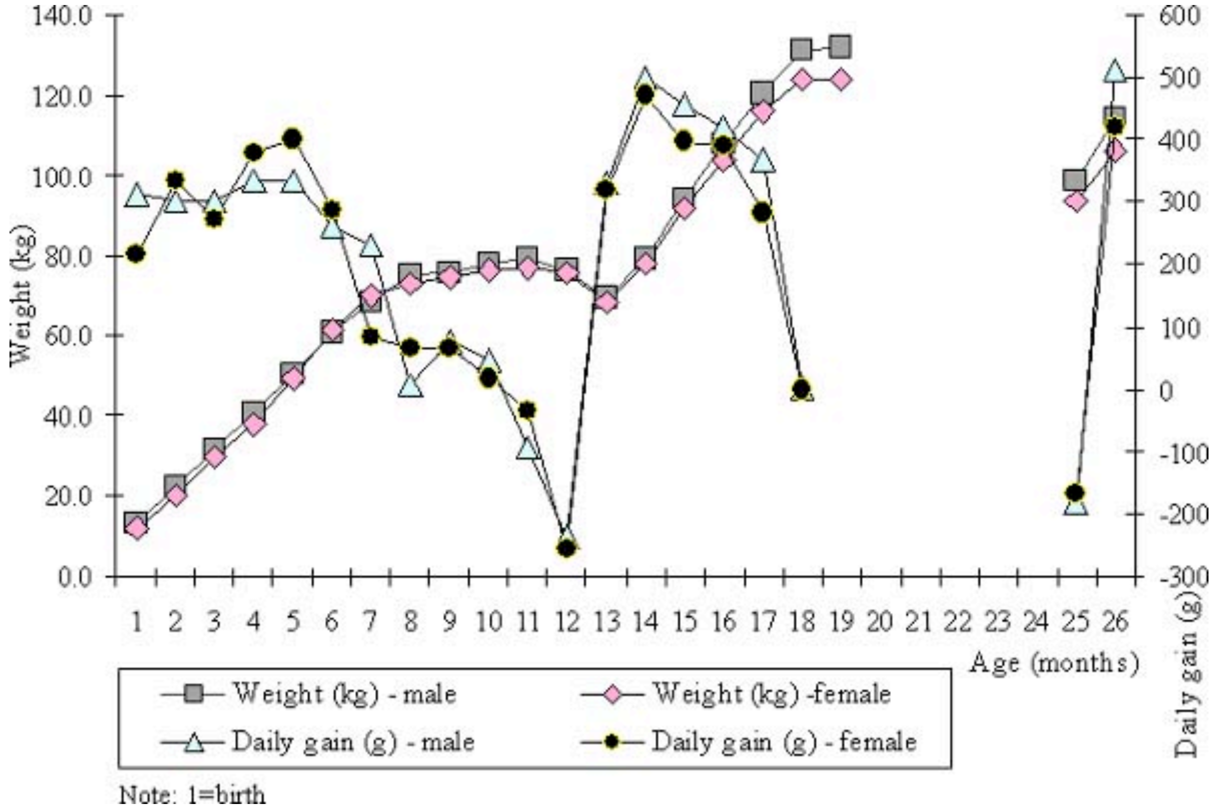
Period of calving (day and month)	Number of calves	Deviation of birth weight (kg)
Prior to 15.4	6	-1.28
16.4 - 30.4	29	-1.67
1.5 - 15.5	26	-1.49
16.5 - 31.5	23	-0.77
1.6 - 15.6	30	-0.98
16.6 - 30.6	18	1.08
1.7 - 15.7	14	4.02
16.7 - 31.7	12	1.09

However, calves born early in the season, March or April, have a longer suckling period ahead of them than those born later in the season. For example, Ma Zongxiang and Dou Yaozong (1982) reported that calves born in March - April reached an average body weight of 45.6 kg by October of that year, while those born in June had attained only 34.2 kg, on average. The calf's growth in the first six months of its life is very important to its subsequent survival over the first winter. Calves born later in the season have a poorer chance of survival over winter than those born earlier.

Seasonal growth of yak. Typically, weight gain in a healthy calf reared by its dam is almost linear over the first six months of life, but declines with the approach of winter; this is followed by some loss in weight over the first winter and spring. Thereafter, in the second warm season, there is again a rapid gain in weight followed, once more, by a loss in weight over the next cold season.

Figure 6.1 illustrates growth from birth to 25 months old of 12 male and 12 female calves of the Plateau type born in April at Longri Breeding Farm of the Pasture Institute of Sichuan. Daily gain for the male calves was fairly constant over the first five months and declined rapidly thereafter. For female calves, weight gain for the first five months was somewhat more variable before declining over winter. In consequence, the weight of the calves increased linearly up to about five or six months of age before remaining more or less unchanged until the following warm season. In the second warm season after birth, weight gains from April/May to August/September were a little faster than in the first year, at between one third and one half kg per day. The third warm season started again with substantial gains in weight after the losses in the previous winter.

Figure 6.1 (a) Body weights of 12 male and 12 female calves born in April at the Pasture Institute of Sichuan, from birth to 25 months old. (b) Daily gain of yak calves monthly from birth to 25 months old.



Similar results (Table 6.5) were obtained with calves of the Alpine type born in May at the Pengbo farm of Tibet (4 000 - 4 600 m a.s.l.), according to the report of Ma Zongxiang and Dou Yaozong (1981).

As shown in Table 6.5, the weight loss of calves over the first winter was around 12 - 15 percent of the weight before the onset of winter. Typically, over the following summer and autumn young yak regain their weight losses and may well double in weight before again losing, over the second winter of life, perhaps 25 percent of the maximum weight reached. The cycle of weight gain and weight loss continues throughout life. This is illustrated in Figure 6.2 by observations on 180 yak steers from birth to five years old (Lu Guanghui 1980). In fully adult yak, the weight loss in the cold season is roughly equal to the gain in the following warm season.

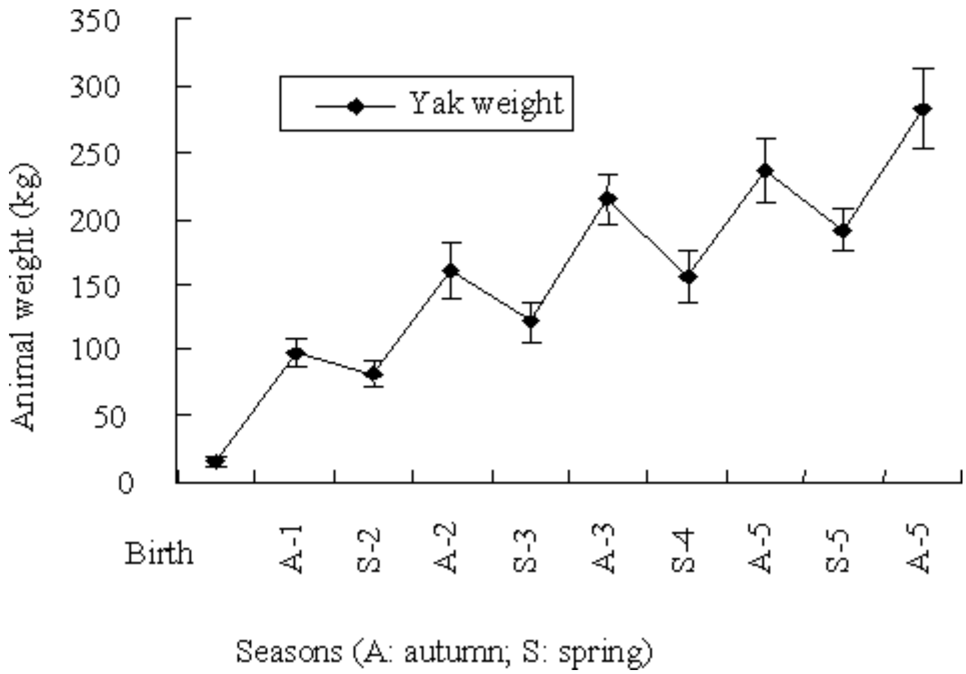
Table 6.5 Monthly change of live weight, monthly gain and daily gain (±SD) of calves (n=14) in cold and warm seasons in Tibet [Source: adapted from Ma Zongxiang and Dou Yaozong, 1981]

Season	**Month**	**Age of calf (months)**	**Live weight (kg)**	**Monthly gain (kg)**	**Daily gain (g)**
Warm season	July	2	21.1 ± 1.5	-	-
	August	3	28.4 ± 2.0	6.3 ± 0.6	213.7 ± 21.1

	September	4	35.2 ± 2.6	5.1 ± 0.8	180.3 ± 19.4
Cold season	October	5	39.0 ± 3.1	5.2 ± 1.0	168.2 ± 11.7
	November	6	38.3 ± 1.8	-0.6 ± 0.3	-23.0 ± 5.1
	December	7	37.2 ± 2.7	-0.4 ± 0.3	-13.3 ± 3.0
	January	8	37.0 ± 4.0	-0.8 ± 0.4	-31.1 ± 1.2
	February	9	37.5 ± 2.3	0.5 ± 0.3	16.2 ± 2.4
	March	10	36.1 ± 1.4	-0.7 ± 0.4	-23.0 ± 3.0
	April	11	37.4 ± 1.3	0.5 ± 0.2	17.0 ± 4.0
Warm season	May	12	32.3 ± 2.4	-5.4 ± 0.2	-188.7 ± 24.1
	June	13	38.5 ± 3.0	8.0 ± 1.2	250.1 ± 25.0
	July	14	45.3 ± 3.4	5.3 ± 1.0	184.5 ± 14.2

Effect of type of rearing on weight gain. The manner in which the yak calf is reared profoundly affects its growth. The three main classes are: 1) to give the calf exclusive access to the milk of its dam (the dam is not milked), 2) to milk the dam once a day and allow the calf the remainder, and 3) to milk the dam twice a day and allow the calf what remains. An additional category (a subdivision of the first class) is that dams that are not milked may a) be allowed to graze at night or b) not be allowed to graze if kept restrained overnight with the yak females that are milked.

Figure 6.2 Changes in the body weight of 180 yak steers from birth to five years old (the first weighting at the date of birth, then at the end of autumn and at the end of spring- start of warm season) [Source: modified from Lu Guanghui, 1980]



There are many studies on the effects of these rearing treatments on calf growth. There is generally a beneficial and quite large effect on calf growth when the calf has access to all the milk of its dam. Often, the largest difference is between calves allowed access to dams milked only once a day compared with those reared by dams milked twice daily. Weight gain under the former regime can be double that from the latter as in the study of Zhang Rongchang (1989) shown in Table 6.6. This is not, however, only a consequence of differences in milk intake by the calf (which are not recorded but estimated to be somewhat greater when the dam is milked only once a day). Normally, the calves are tethered when their dams are milked. When the dam is milked only once daily, the calf is tethered and kept apart from the dam for a relatively short time only and grazes and drinks water alongside the dam for most of the day. Calves with dams milked twice a day are tethered for much of the day and have perhaps only four to five hours of time during which they move around at pasture with their dams. In a similar study by Yang Rongzhen *et al.* (1997), the main difference in growth of calves was between those from dams not milked compared to those milked - with, unusually, no effect due to frequency of milking. In this study, calves at the age of 18 months weighed around one third less if their dams were milked than if they were not milked.

Table 6.6 Live weight and daily gain (±SD) of calves with different rearing methods [Source: adapted from Zhang Rongchang, 1989]

Age (month)	**Sex**	**No.**	**Not milked**		**Milked once daily**		**Milked twice daily**	
			Live weight (kg)	**Daily gain (g)**	**Live weight (kg)**	**Daily gain (g)**	**Live weight (kg)**	**Daily gain (g)**
Birth	M	32	15.4 ± 3.5	-	15.9 ± 2.4	-	16.7 ± 1.3	-

	F	30	17.8 ± 2.9	-	17.3 ± 4.0	-	15.4 ± 2.4	-
6	M	32	120.1 ± 13.2	558.3 ± 33.2	100.4 ± 9.1	482.3 ± 21.4	55.9 ± 5.6	229.8 ± 12.5
	F	30	110.9 ± 10.2	533.1 ± 24.6	98.1 ± 5.6	456.9 ± 18.3	54.4 ± 3.4	215.2 ± 15.8
12	M	30	142.2 ± 7.8	349.9 ± 21.1	115.6 ± 7.7	287.2 ± 20.0	87.9 ± 7.2	194.2 ± 10.7
	F	30	125.3 ± 12.6	303.3 ± 19.3	110.0 ± 4.9	256.1 ± 14.3	84.3 ± 8.8	192.8 ± 15.4
18	M	30	256.1 ± 18.5	440.1 ± 22.4	233.6 ± 12.3	402.1 ± 23.9	160.1 ± 6.9	276.0 ± 20.1
	F	30	212.2 ± 14.3	383.4 ± 15.5	214.3 ± 10.2	366.1 ± 21.1	155.8 ± 9.7	255.6 ± 23.5

In another group trial conducted by Cai Li in Sichuan (at 3 450 m altitude), the six-month weight of calves from dams milked once a day was 93.1 kg compared with 48.5 kg for those with dams milked twice daily. At the Datong cattle farm in Qinghai, calves with dams that were not milked weighed 104.7 kg at six months old compared with 70.2 kg for those with dams milked once daily. Clearly, milking the dams and the associated separation of the calf from its dam adversely affected the weight gain of the calves.

Some calves suckle their dams for a second year and are not weaned until the end of the second warm season of their life. The dams lactating for that second season are those that have not calved again. Table 6.7 shows some results on a method of rearing on calf growth over a period of 92 days during their year of birth and then in the second year. (The results for the second year are all based on calves from dams that were milked once daily in the year in which their calf was born. In this trial, the females not milked were further divided into those that were confined at night along with their calves and those allowed to graze at night as well as during the day.)

It is seen that the additional grazing allowed to the dams and calves at night led to a substantial increase in the weight gain of the calves. Compared to the growth of calves confined at night along with their dams, milking of the dam once a day had no further detrimental effect at either age of calf - but milking twice a day and the attendant further restrictions on the calf reduced calf growth further (data for year of birth only). This seems to contrast with the larger effects of milking the dam, noted earlier, in the results of Zhang Rongchang (1989) and Cai Li (however, it is not explicitly stated for those studies whether the calves or their dams were confined at night or not). In view of the large, adverse effect of night confinement on calf growth shown in Table 6.7, it should be said that there are good reasons, apart from tradition, why it may not be possible everywhere to adopt a practice of night grazing for the calf alongside its dam. Thus, in many areas, yak calves need to be confined at night for reasons of safety and, if feasible, to provide their dams an undisturbed night's grazing prior to the morning milking.

Hand rearing of yak calves is restricted to situations where there is no alternative. Usually when a calf has lost its dam, it is fostered on a yak cow that has lost her calf (see Chapter 8). Data on the effects of artificial rearing on growth have not been obtained.

Breed and sex differences in growth. It is generally accepted that yak of the Alpine type, and especially the Jiulong breed (perhaps the best of the Alpine type), grow more rapidly than those of the Plateau type.

Table 6.7 Weight gain of yak calves in two successive years, according to rearing method [Source: Xu Guilin, 1985]

Dam	No.	Weight gain [92 days] (kg)
Year calf born (calf age 0 year)		
Not milked - dam and calf confined	14	29.0
Not milked but grazing at night	17	60.8
Milked once daily	26	28.1
Milked twice daily	29	20.2
Year after calf born (calf age 1 year)*		
Not milked - dam and calf confined	32	28.8
Not milked but grazing at night	9	49.8
Milked once daily	27	29.7

* The results are all based on calves from dams that were milked once daily in the year in which their calf was born.

The cautionary note has to be repeated that, normally, these different types and breeds are not at the same location at the same time and that yak type or breed are therefore confounded with location and the environmental differences implicit in that. This applies to the data shown in Table 6.8.

The greater growth of the Jiulong yak compared with the Maiwa yak (Table 6.8) appears to be a function not only of a larger final weight but also a faster early growth rate relative to that weight (since these results do not extend beyond the age of six and a half years, it is not known whether the weights at that stage are true mature weights although herdsmen usually regard the animals as "mature" by that age - see ensuing explanations).

By three to three and a half years old, the Jiulong males described in Table 6.8 had reached nearly 58 percent of their six- to six-and-a-half-year-old weight while the Maiwa had reached only 41 percent (for females the corresponding percentages are 78 percent and 70 percent, respectively). However, it is not known how these results may have been affected by the different environments in which the two breeds were kept. It is nonetheless apparent from Table 6.8 that for each breed the females grew faster relative to their final ("mature"?) weight in the early years of life than did the males. However, the growth of the females slowed after they reached the age of about four years. The males still continued to increase in weight quite markedly after that age - to reach a substantially greater final weight than the females. The growth differences between the sexes are reflected by the practice of the herdsmen to regard females as suitable for transfer to the adult herd at the age of four, whereas males are not regarded as "mature" (and at the height of their powers) until the age of six or seven.

Table 6.8 Estimated body weights* of Maiwa and Jiulong male and female yak (at separate locations) from birth to six and a half years old and weight at each age relative to final weight* (weights in October/November of each year). [Sources: Maiwa - Chen Xaifei *et al*., 1981; Jiulong - Cai Li *et al*., 1980a]

	Maiwa								**Jiulong**							
	Male				**Female**				**Male**				**Female**			
Age (yrs)	**No.**	**Wt (kg)**	**[SD]**	**% of final**	**No.**	**Wt (kg)**	**[SD]**	**% of final**	**No.**	**Wt (kg)**	**[SD]**	**% of final**	**No.**	**Wt (kg)**	**[SD]**	**% of final**
Birth	77	13.4		3.2	71	11.9		5.4	27	15.9	2.3	3.6	24	15.0	2.5	5.0
1 - 1.5	84	65.9	2.2	15.9	82	67.0	11.3	30.2	34	145.3	20.8	30.7	35	124.9	25.2	40.2
2 - 2.5	33	120.1	19.7	29.0	35	119.6	28.5	53.9	18	208.6	25.5	44.0	21	189.6	29.4	61.0
3 - 3.5	30	170.7	25.8	41.3	61	154.8	28.5	69.8	3	272.6	25.6	57.5	11	243.1	23.2	78.3
4 - 4.5	15	302.3	49.5	73.1	73	181.9	21.2	82.0	11	312.5	19.2	65.9	26	269.7	18.3	86.8
5 - 5.5	10	375.3	69.8	90.7	40	188.7	42.6	85.1	7	386.0	20.1	81.4	9	283.1	33.9	91.1
6 - 6.5	17	413.8	67.0	100	21	221.8	25.9	100	38	474.1	38.8	100	10	310.6	26.9	100

* Final weight is that at 6 or 6.5 years old and is not necessarily the weight at full maturity.

The difficulty of interpreting data on size and other aspects of the performance of yak as presented here, and in the literature on the yak in general, rests on the fact, as already noted, that conditions under which yak are kept vary from locality to locality and between years and that these factors are also often confounded with the type or breed of yak and with the management system. This point is further exemplified by Sarbagishev *et al*. [1989] who note that yak in Kyrgyzstan are considerably larger than those in neighbouring Tajikistan because in the former country, yak are not milked but kept exclusively for meat production. Under good grazing conditions on state farms in Kyrgyzstan, the researchers recorded weight gains during 12-month fattening periods well in excess of 100 kg live weight per year. These gains were made both in the second year of life (107 kg for 248 yak) and the third year of life (126 kg for 87 yak) and they were only a little less in the year after that (92 kg for 11 animals). That these weight gains are markedly higher than those shown in Table 6.8 for Maiwa and Jiulong yak should occasion no surprise since the Maiwa and Jiulong were not specifically managed as "fattening" animals. The higher growth rates on the state farms in Kyrgyzstan illustrate, however, that yak do have a higher potential for growth than is sometimes realized in the predominantly harsh conditions in which they are normally kept.

Linear body dimensions

Height at withers, body length, chest and girth circumferences and the estimated body weight from linear body dimensions of adult male and female yak at different locations in China are presented in Table 6.9 (Zhang Rongchang, 1989). These data testify to the fact that the size and performance of yak vary with locations and the type or breed of yak kept at these locations. Generally, yak in Sichuan have the biggest body size and those in Tibet the smallest; and the yak of the Alpine type has a larger body size than that of the Plateau type.

Chen Zhihua *et al*. (2000) collated evidence on environmental factors and concluded that the annual average temperature and precipitation were the most important among the environmental (ecological) factors affecting growth of yak (see also Chapter 4). As evidence of the importance of the environmental factors on body size and growth, it is possible to point to differences in size and weight at similar ages of the same "breed" at different locations. This further reinforces the caution that must be attached to comparisons (such as breed comparisons) across locations. Correlations among the body dimensions were reported to be of the order of 0.3 - 0.5 and those of the linear dimensions with body weight in the range of 0.5 - 0.6 ($P < 0.01$) (Wen Yongli and Chen Zhihua, 1994).

Table 6.10 shows the increase in linear body dimensions over a period of years. As already noted in respect of body weight (cf. Table 6.8) the females mature earlier than the males, as apparent from the higher proportion of last observed size (four years old in this case) reached by each body dimension at each of the earlier ages.

Table 6.9 Linear body dimensions and body weight (±SD) of adult yaks of different types and breeds at different locations in China [Source: adapted from Zhang Rongchang, 1989]

Location	Breed	Sex	No.	Height at withers (cm)	Body length (cm)	Chest circumf. (cm)	Girth circumf. (cm)	Body weight* (kg)
Tibet	Alpine**	M	39	122.2 ± 3.5	142.0 ± 6.6	167.8 ± 6.4	18.9 ± 2.3	293.5 ± 20.4
		F	529	110.1 ±	125.1 ±	150.4 ±	15.4 ± 1.2	197.1 ±

				4.8	3.9	4.8		16.4
	Plateau***	M	20	116.6 ± 7.9	141.3 ± 5.9	169.6 ± 5.9	18.4 ± 1.9	282.4 ± 23.8
		F	225	103.3 ± 5.5	126.1 ± 6.8	145.2 ± 9.1	15.2 ± 1.0	187.9 ± 19.0
Yunnan	Zhongdian	M	23	119.1 ± 8.1	126.9 ± 11.6	162.2 ± 10.8	17.6 ± 1.1	234.6 ± 35.8
		F	186	105.2 ± 5.3	117.1 ± 8.3	153.7 ± 22.9	16.1 ± 1.0	192.5 ± 27.5
Sichuan	Jiulong	M	15	137.5 ± 8.8	172.6 ± 13.4	218.6 ± 26.7	23.64 ± 1.5	593.5 ± 184.9
		F	708	116.6 ± 4.3	140.3 ± 7.8	178.5 ± 7.8	18.2 ± 1.3	314.4 ± 38.6
	Maiwa	M	17	126.0 ± 5.0	157.3 ± 10.4	193.4 ± 9.2	19.8 ± 0.8	413.8 ± 67.0
		F	219	106.2 ± 4.5	130.7 ± 7.3	154.6 ± 11.6	15.57 ± 1.0	221.8 ± 25.8
Qinghai	Plateau***	M	21	129.2 ± 6.2	150.6 ± 5.98	194.4 ± 7.7	20.10 ± 1.1	444.0 ± 54.7
		F	208	110.9 ± 4.9	131.9 ± 5.1	157.2 ± 6.3	15.8 ± 1.1	256.4 ± 81.2
	Huanhu	M	14	113.9 ± 6.5	143.7 ± 14.9	169.0 ± 15.3	18.3 ± 2.3	323.2 ± 100.6
		F	138	103.0 ± 0.3	123.8 ± 7.6	147.0 ± 6.9	15.4 ± 1.2	210.6 ± 34.5
Gansu	Tianzhu White	M	17	120.8 ± 4.5	123.2 ± 4.7	163.8 ± 5.5	18.3 ± 1.1	264.1 ± 18.3
		F	88	108.1 ± 5.5	113.6 ± 5.2	153.7 ± 8.0	16.8 ± 1.8	189.7 ± 20.8
	Gannan	M	31	126.6 ± 6.4	141.0 ± 8.4	187.9 ± 10.8	21.3 ± 2.2	355.1 ± 35.7
		F	378	107.6 ± 5.6	118.8 ± 7.5	154.7 ± 6.9	16.3 ± 1.3	210.5 ± 26.4
Xingjiang	Bazhou	M	33	126.8 ± 6.2	140.1 ± 10.4	192.4 ± 11.8	20.7 ± 1.3	362.6 ± 22.6
		F	265	110.7 ± 2.5	123.5 ± 5.7	171.2 ± 9.1	16.3 ± 0.7	250.4 ± 21.3

* Estimated from body dimensions to avoid possible confusion over the breed nomenclature used in this Table. **"Alpine" yak in southeastern Tibet normally regarded

as home to the Jiali and Pali breeds. *** "Plateau" yak in northwestern Tibet normally regarded as home to the Pali breed.

Table 6.10 Linear body dimensions (cm ±SD) of yak at different ages [Source: Zhong Guanghui *et al.*, 1996a]

Sex	Age (yr)	No.	Height at withers	Chest depth	Chest width	Hip width	Heart girth	Cannon bone circumf.	Rump length	Body length
M	1	226	94.8 ± 20.7	44.4 ± 6.0	20.1 ± 2.7	23.8 ± 3.0	119.7 ± 12.9	13.7 ± 1.0	31.9 ± 3.5	99.8 ± 8.3
	2	155	104.4 ± 5.5	53.9 ± 5.4	23.9 ± 3.9	27.8 ± 3.3	138.5 ± 10.2	15.4 ± 1.1	36.1 ± 2.6	114.8 ± 7.9
	3	116	110.9 ± 5.7	58.6 ± 5.1	25.8 ± 3.5	30.4 ± 3.3	153.6 ± 13.0	16.5 ± 1.1	38.9 ± 3.8	124.5 ± 12.9
	4	91	122.4 ± 8.6	67.9 ± 7.8	32.3 ± 8.2	36.9 ± 6.8	177.6 ± 18.6	18.8 ± 1.9	45.0 ± 5.3	140.2 ± 12.6
F	1	220	91.5 ± 6.3	43.8 ± 5.3	20.2 ± 5.7	23.2 ± 3.0	117.4 ± 11.0	13.4 ± 1.0	30.4 ± 3.5	97.4 ± 8.7
	2	157	101.6 ± 5.3	51.6 ± 4.3	23.7 ± 4.4	27.6 ± 2.8	134.3 ± 13.7	14.7 ± 1.0	34.9 ± 3.9	111.4 ± 11.4
	3	181	107.1 ± 4.9	56.2 ± 3.7	24.5 ± 3.2	30.7 ± 3.6	147.6 ± 9.7	15.7 ± 0.9	37.5 ± 2.4	120.0 ± 6.7
	4	190	110.8 ± 6.3	58.9 ± 6.0	25.4 ± 5.2	32.2 ± 3.4	153.4 ± 11.7	16.1 ± 0.7	39.0 ± 2.2	126.1 ± 7.6
	5	160	112.1 ± 4.5	60.9 ± 3.2	25.8 ± 3.9	33.4 ± 3.4	158.1 ± 9.7	16.3 ± 0.6	40.3 ± 2.2	127.5 ± 11.2

Females at one year had reached between 5 percent and 10 percent more of their size at four years old than did the males. The results also show, as is well established in the literature, that some body parts such as height at withers and cannon-bone circumference, mature relatively earlier in life than do others such as chest depth and hip width (with body weight continuing to increase significantly even after the linear dimensions have virtually stopped growing).

Wen Yongli and Chen Zhihua (1994) published results on body dimensions of Maiwa yak that also show similar relative rates of maturity of the different body parts and of body weight and the relatively later maturity in males than in females.

In the yak, as in other bovines, the linear body dimensions show less seasonal variation in size than is found for body weight (a cubic measure of size). Results are shown in Table 6.11 - albeit over a period of only two years. Moreover, relatively early-maturing dimensions that are largely a function of skeletal size, such as height at withers, show less variability in size over the seasons (there was no decline in size over winter) than dimensions that mature later and also include, in the measurement, a greater proportion of muscle and fat (e.g. heart girth).

Table 6.11 Height at withers, body length, and heart girth of yak over a two-year period (measurements in cm. are given for the unweighted average of 12 male and 10 female animals) [Source: Sichuan Grassland Institute, 1982]

Age (month)	Height at withers	Body length	Heart girth
Birth	50.8	45.7	56.8
6	79.1	86.6	104.9
12	88.9	88.5	102.7
18	93.1	107.1	135.1
24	95.8	108.5	128.6

Milk production

General considerations

There is, at present, no breed or strain of yak developed especially for milk production. All breeds are kept, to a greater or lesser extent, to produce milk, in addition to their other uses and products. Milk yield is closely related to pasture growth and quality and, in general terms, the amount of milk produced by the yak cow is considered as no more than the amount needed for the normal growth and development of its calf. In this respect, the milk yield of yak is more akin to that of animals in the wild than to the milk yield of dairy cattle. Even though the milk may be taken from the yak cows at the expense of the calf, milk and milk products of yak are important for the herdsmen and their families, in China and in most other yak-keeping countries. In commercial terms, milk is perhaps the most important of the yak products. The F1 hybrids with other cattle produce substantially more milk than the pure yak - the actual amount depending on the cattle breed used to produce the hybrid. The F1 hybrid has, therefore, considerable value to the herdsmen in the right situation.

When considering estimates of the milk production of yak, account has to taken of the milk consumed by the calf - which can only be estimated - and the quantity extracted by the herders. As a rule, yak females are not milked for the first month after calving, though perhaps only the first two weeks in some areas. During that time, the calf takes all the available milk, including the colostrum, on the day or two days after calving. As in other cattle, the quality of the colostrum of yak cows is much better than the milk produced thereafter (Liu Haibo, 1989; Zhang Rongchang, 1989). Table 6.12 shows that the total solid content of the colostrum from yak is about twice that of the later milk, while milk protein content can be three times as high and fat content between two- and three-fold of that in the later milk.

Table 6.12 A comparison of composition between colostrum and normal milk in yak [Source: adapted from Liu Haibo, 1989 and from Zhang Rongchang, 1989]

Species	No.	Milk type	Milk solid (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)	Density kg/litre
Yak	17	Colostrum	32.0 - 34.5	13.2 - 15.8	15.1 - 17.1	1.7 - 1.9	0.9 - 1.1	1.03 - 1.07
Yak	33	Normal milk	16.9 - 17.7	5.5 - 7.2	4.9 - 5.3	4.5 - 5.0	0.8 - 0.9	1.03 - 1.04

After the initial period when the calf obtains all the milk provided by the dam, it is estimated that the calf takes about a third of the available milk if the yak cow is milked twice daily and about half the milk with once-a-day milking. Yak females produce about a third more milk, in total, if stimulated by milking twice daily compared with once a day (39 percent more in a study by Cai Li in Sichuan, and 26 percent more in an investigation in Qinghai (Lei Huanzhang *et al*., 1983)).

There is no generally agreed upon method of assessing yak lactation milk yield. Production over a lactation period of 180 days has been proposed and estimated from the yield on three to five successive days and the use of coefficients based on the month in which the milk yield is measured. The coefficients, in turn, are based on the fact that yield is higher in months of high pasture growth than either at the beginning or end of the grass-growing season. To the estimate of yield derived from hand milking has to be added an estimate of milk consumed by the calf. Though such methods of estimating yield are attractive in principle, they suffer from the further difficulty that the coefficients for different months vary greatly for different locations and dates of calving; hence the absence of general agreement on the use of these methods.

Table 6.13 Milk yield and fat percentage of yak females of different breeds at various locations of China (± SD)

Province	Yak breed or yak location*	Month of measurement	No.	Average Daily yield (kg)	Estimated lactation yield (kg) (in days)	Fat (%)	Source
Gansu	Tianzhu	5 - 10	223	2.3 ± 0.5	304 (135)	6.8	Zhang

	White					± 1.3	Rongchang, 1989
Gansu	Plateau (in Shandan)*	5 - 11	21	2.6 ± 0.6	464 (180)	5.4 ± 1.5	Zhang Rongchang, 1989
Gansu	Gannan	5 - 10	15	1.8 ± 0.2	315 (177)	--	Research Co-operative Group, 1980-1987
Qinghai	Plateau	6 - 10	181	1.4 ± 0.3	214 (153)	5.6 ± 1.2	Research Cooperative Group, 1980-1987
Qinghai	Huanhu	6 - 10	96	3.0 ± 0.3	487 (153)	6.4 ± 1.4	Zhang Rongchang, 1989
Qinghai	Guoluo*	7 - 11	20	1.0 ± 0.2	162 (153)	6.6 ± 0.7	Li Quan *et al.*, 2000b
Sichuan	Maiwa	4, 7	20	1.8	365 (150)	6.8	Chen Xiafei *et al.*, 1981
Sichuan	Jiulong	7, 8	93	2.8 ± 0.2	414 (150)	5.7 ± 1.0	Cai Li *et al.,* (1980a)
Tibet	"Plateau"*	7 - 9	19	2.7 ± 0.3	280 (105)	--	Zhang Rongchang, 1989
Tibet	Alpine*	8 - 10	41	0.92		6.4	Research Co-operative Group, 1980-1987
Tibet	Jiali **		48	0.8 ± 0.2	148 (180)	6.8 ± 1.3	Ji Qiumei *et al.*, 2000a
Tibet	Pali **		25	1.0 ± 0.2	200 (180)	5.9 ± 0.7	Ji Qiumei *et al.,* 2000a
Tibet	Sibu**		36	0.9 ± 0.1	180 (180)	7.5 ± 1.4	Ji Qiumei *et al.*, 2000a
Yunnan	Zhongdian	5, 7, 11	81	1.1 ± 0.2	132-302 (180-210)	6.2 ±	Zhang Rongchang,

						1.6	1989

* Location of yak within the province - for Tibet: "Plateau" here refers to Pali breed, Alpine to Jiali.
**Yields for these breeds are based on varying proportions of yak females in the lactation following calving and a lactation in a second year without calving again ("half lactation"). The "full lactation" yields for these breeds as shown in Table 11.5 (Chapter 11) are Jiali:192; Pali: 215; Sibu: 216.

Factors influencing milk yield

Breeding

Table 6.13 provides the estimated milk yields and fat content in milk of different yak breeds at various locations in China. These yields are the amounts milked by hand with an adjustment for milk taken by the calves. Table 6.13 indicates that, in general, the milk yield of the yak is low, but the fat content is relatively high. The results also suggest that the Huanhu yak in Qinghai had the highest milk yield and yak in Tibet had mostly the lowest.

Table 6.14 Milk production in crossbred* and domesticated yak [Source: adapted from Jialin *et al*., 1998a]

Month	**Crossbred yak (n=20)**					
	Daily milk yield (kg)		**Fat content (g/kg)**		**Monthly milk yield (kg)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
May	1.1	0.02	47.5	3.6	32.9	6.0
June	1.7	1.2	53.5	8.7	49.8	6.7
July	2.1	0.17	49.4	4.9	60.4	5.2
August	2.3	0.28	57.7	5.4	68.9	8.5
Significance						
Milk yield over 120 d (kg)			Mean = 212.2		SD = 20.2	
Mean daily milk yield (kg/d)			Mean = 1.7		SD = 0.16	
Mean fat content (g/kg)			Mean = 52.0		SD = 2.9	
	Crossbred yak (n=10)					
	Daily milk yield (kg)		**Fat content (g/kg)**		**Monthly milk yield (kg)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
May	1.1	0.21	50.9	14.6	33.3	3.5
June	1.1	0.21	50.9	14.6	33.3	3.5
July	1.7	0.10	47.6	8.5	51.2	3.0

August	1.8	0.28	68.8	6.7	54.6	8.5
Significance						
Milk yield over 120 d (kg)			Mean = 184.5		SD = 10.5	
Mean daily milk yield (kg/d)			Mean = 1.5		SD = 0.10	
Mean fat content (g/kg)			Mean = 53.5		SD = 4.1	

** Wild yak semen was used to inseminate domestic yak cows to produce the crossbred.

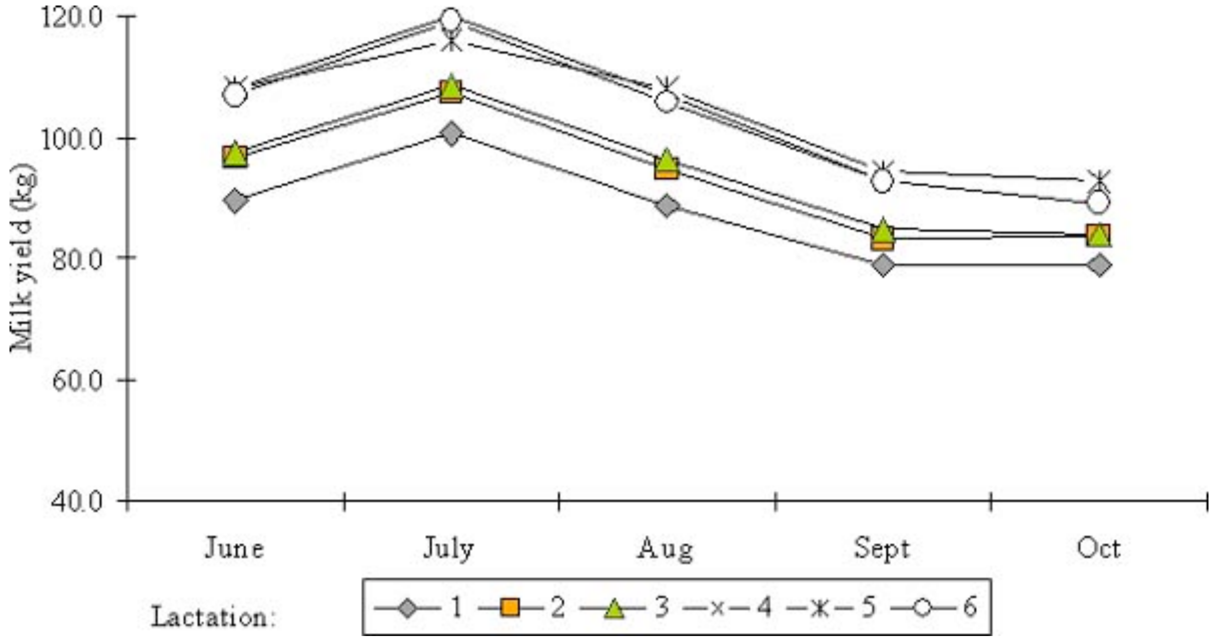
As stressed in respect of other breed comparisons in this book, some caution is needed in interpreting the variation in milk yield among the breeds: The "breed" differences may be associated with different herd sizes, forage availability, daily milking times (once a day or twice a day) and with differences in management among locations. Also, as noted elsewhere in this book, even estimates for the same breed can vary among different studies because different conditions apply to the observations.

Table 6.14 shows that a herd of crossbred yak (domestic yak dam crossed with wild yak sire), milked once daily after suckling of the calf, had a higher daily milk yield and total lactation milk yield than ordinary domestic yak, but there was no overall difference in the fat content of the milk.

Effects of age and parity

Lactation milk yield increases with the age of the female up to about 10 or 11 years old and also with the number of calvings (Zhang Rongchang *et al*., 1983; Xu Guilin *et al*., 1983) - although these two factors are rather closely associated with each other. Figure 6.3 shows seasonal changes in yield in six different lactations.

Figure 6.3 Milk yield of yak females in five (warm) months of the year in six separate lactations (Number females per lactation: 1:20; 2:20; 3:13; 4:10; 5:10; 6:18)



There appears to be no evidence to show that yak cows have a lactation peak in relation to calving date - as found in dairy cattle; an overriding effect on milk yield in the yak seems to be that of pasture growth, reflected by month, in each of the six lactations as seen in Figure 6.3. Similar effects of parity and the month in which the cows lactate have also been shown for Jiulong yak (at an elevation of 3 200 m) in a substantial study by Wen Yongli *et al*. (1994) involving between 65 and 128 animals in each parity group.

Other correlations with milk yield

Lang Jie *et al*. (1999) reported that in breeding groups of Maiwa yak the correlation of milk production of mother and daughter was positive and linear ($r=0.374$, $P<0.05$) - of course, this does not provide an estimate of the heritability (the strength of inheritance) of milk production in yak. These authors also reported that the sizes of various linear body dimensions of yak in their first lactation are positively (and significantly) correlated with milk production (r in the range of 0.32 - 0.56). This shows a tendency for the better-grown females to yield more milk. This correlation was much weaker for female yak in later lactations.

Environmental factors affecting milk yield - the lactation curve

Herbage supply. As referred to earlier, one of the important factors influencing milk yield is pasture production - the quantity, growth status and nutritive value of the herbage. These are, in turn, affected by climate and season (cf. Chapter 13). All lactating yak, irrespective of age, parity or breed type and even location, tend to peak in yield in July and August when grass is at its best in terms of quality and quantity (cf. Figure 6.3). These months are known in yak-producing areas of China as the "golden age". Before July, though the grass has started to turn green and to grow, the amount of grass available is not high. After August, as air temperature falls, the nutritive value declines - as the grass produces seeds and then wilts, and the content of crude fibre of the grass is high. Table 6.15 provides some information on the composition of grass (but not on grass quantity) from samples taken on pastures at an elevation of 3 600 m in Hongyuan county of Sichuan province. The pasture samples were representative of the herbage grazed by the yak. (For more information on composition of different pasture species, see Chapter 13.)

Table 6.15 Percentage composition (on a dry-matter basis) of grass on meadow in different months over the warm season [Source: Sichuan Grassland Institute, 1982]

Date	Dry matter	Crude protein	Crude fibre	Ash	N-free extract	Calcium	Phosphorus
9 June	24	18.8	27.9	5.0	42.0	0.50	0.25
30 June	28	11.8	30.0	5.0	48.6	0.43	0.25
30 July	33	12.4	27.6	6.1	50.9	0.42	0.33
30 Aug.	38	10.0	30.8	8.2	48.9	0.61	0.26
29 Sept.	42	8.1	33.3	5.7	50.5	0.62	0.14
31 Oct.	62	4.8	34.8	5.0	53.5	0.53	0.16

Month of milking. In Hongyuan county, from where the data on grass composition in Table 6.15 were derived, the peak of monthly milk yield was in July for yak cows and in June for hybrids (both F1 [*Pian Niu*] and backcrosses to cattle [one quarter-bred yak]). The monthly yields and the fat percentage of the milk are shown in Table 6.16.

Table 6.16 Monthly milk yield and fat percentage of milk of yak, F1 (*Pian Niu**), and one quarter-bred yak** in Hongyuan county of Sichuan

		No.	June	July	Aug.	Sept.	Oct.	Nov.	Total
Yak	Milk yield (kg)	13	40.4	40.6	37.3	27.0	20.0	11.0	176.5
	Fat percent	6		5.6	6.6	6.5	7.6	7.8	6.8
(F1)	Milk yield (kg)	12	64.7	61.3	43.1	29.5	17.9	11.0	227.5
	Fat percent	5		5.1	5.4	5.8	6.8	6.6	5.9
¼-bred yak	Milk yield (kg)	10	48.5	40.9	40.9	29.5	19.4	6.7	185.9
	Fat percent	7		6.0	6.0	6.0	7.0	7.6	6.6

* The one half-bred yak from local *Bos taurus* (yellow cattle) bulls used for crossing with yak.

**The one quarter-bred yak are backcross offspring of the F1 (*Pian Niu*) dams mated to bulls of the yellow cattle.

The milk yields of the cows represented in Table 6.16 are lower than those represented in Figure 6.3, but both show the seasonal decline in milk production. It is also seen that, as found in dairy cattle, that the percentage of fat in the milk increases as the season advances and the quantity of milk declines.

Similar results to those presented on the period of peak lactation have been obtained from various locations, all showing that the supply of grass is the major factor influencing yield and that parity of cow has a much smaller effect. Another aspect of this, from a more northerly region (the Vostochnyi Sayan area of the Russia Federation), derives from a study of Katzina (1993). She reports that yak which had calved early in the year, in April, attained their maximum udder volume in the third month of the lactation, while those that did not calve until June attained their maximum udder volume of yak in the first month of lactation. Thus, both groups would have their largest udder volume around the same month of the year.

Month of calving. The study by Katzina (1993) also showed that yak that had calved in April had a maximum udder volume, which was far greater (two-and-a-half-fold) than that of yak that calved in June. The April-calving yak, in that part of the Russian Federation, lactated for six to seven months to produce around 360 kg milk while those that did not calve until June lactated for only four to five months to produce 150 kg of milk on average.

An interrelationship between the month of calving and the month of milking is shown particularly well in Table 6.17, with data from Mongolia. This re-affirms the month of milking as the most important variable for milk production - reflecting the importance of growth and quality of the available herbage.

Table 6.17 Monthly milk yield of adult cows (based on quantity milked plus amount of milk taken by calf) according to month of calving and month of milking [Source: State and Cooperative Farms: Bat-Erdene, 1993]

Month of milking*	**Month of calving**			
	March	**April**	**May**	**June**
1	65.2 (41 - 91)	70.1 (49 - 94)	70.1 (58 - 100)	112.6 (82 -128)
2	63.6 (47 - 85)	63.3 (48 - 81)	101.5 (67 - 154)	**118.3 (79 - 132)**
3	64.3 (41 - 90)	105.5 (71-130)	**108.5 (78 - 146)**	102.0 (71 - 111)
4	107.9 (76 -158)	**107.3 (93 - 132)**	109.3 (80 - 153)	87.2 (62 - 97)
5	**115.8 (87 - 174)**	99.8 (71 - 126)	82.0 (64 - 109)	65.6 (37 - 94)
6	104.7 (73 -151)	83.5 (68 - 107)	61.9 (44 - 90)	48.1 (27 - 84)
7	84.5 (59 - 119)	58.8 (40 - 84)	40.5 (25 - 90)	29.7 (16 - 31)

8	60.4 (42 - 90)	52.9 (25 - 73)	33.5 (16 - 48)	
9	44.7 (25 - 84)	31.3 (16 - 43)		
10	26.1 (16 - 45)			

* Month of milking counted from month of calving (e.g. calving in May, first month of milking is May, second month of milking is June etc.) **July**, as the month of milking, is shown in bold

Weather. Xu Guilin *et al*. (1983) recorded that the weather conditions on the day of milking affected yield on that day. Thus, in comparison with milk produced on a clear day, milk production on a cloudy day was 1.9 percent higher and on a rainy day 7.7 percent greater. Zhang Rongchang (personal communication, 2000) also found that variation of milk yield due to the weather condition can be up to around 8 percent. According to the Qinghai Provincial Meteorological Bureau, the optimum temperature for yak is around 5° - 13°C (Zeng Wenqun and Chen Yishi, 1980). Yak appear to produce less milk when the ambient temperature is too high especially when this is associated with strong solar radiation and a lack of wind on a clear day. Conversely, more milk is produced during cloudy or rainy conditions. It is not immediately obvious whether the small increases in milk production associated with the weather result from an increased intake of herbage or of water, or some other factors related to the environment - or from associated variation in the metabolic rates of the yak (the latter possibility being favoured by Zhang Rongchang, personal communication, 2002).

Effects of winter and cessation of milking. As air temperature starts to fall after October and winter approaches rapidly, hand milking of the yak females is normally stopped. As indicated earlier, a yak does not dry off in consequence of this and continues to secrete a little milk for its calf. This happens irrespective of whether a female yak is pregnant or not. Only a cow that has lost her calf during the warm season will dry off when hand milking ceases. Similarly, a female that is pregnant but has been isolated from her previous calf will dry off when hand milking stops. Other pregnant females with a calf still at foot will not go dry until their one-year-old calf is removed prior to the next calving. Finally, a cow, even though not pregnant at the onset of winter but still suckling a calf, will continue to lactate through the following warm season and, normally, will be hand milked again. The "half-lactating" female yak (as it is called) will stop being milked at the end of her second warm season and will then go dry, irrespective of whether she is pregnant or not.

Supplementary feeding. Some trials have been conducted with supplementary feeding of conserved grass - silage, hay or straw - during winter months to study the effect on the subsequent lactation. In this context, Long *et al*. (1999a) reported a trial with 33 Tianzhu White yak cows at grazing that were given supplementary feeds of 1.0 - 1.5 kg highland barley straw or oat hay per animal per day, from the beginning of December to the end of April. This supplementation resulted in an increased lactation length ($P<0.01$) over the whole milking period, but there was no difference attributable to the type of straw used.

Milk yield was also increased, but not significantly, perhaps because the supplementary feeding was stopped before calving began (see also Chapter 13 and Table 13.17).

Zhou Shourong (1984) conducted a trial with nine yak cows in Sichuan in the winter months. He found that supplements of 4 kg of silage per head per day led to a rise of milk output from 150 to 350 g per day, after only seven days of supplementary feeding and to 500 g of milk after 15 days of feeding.

However, the difficulties and costs involved in conserving grass as hay (other material is usually not available) may make supplementary feeding uneconomic over the winter and spring as a means of promoting milk production at that time of year. Silage, as used in the trial referred to above, is not a frequent option as it freezes solid in the cold winter conditions of the region if not very heavily and expensively protected. It is relevant to note in the context of supplementary feeding, that the yak cows are not in good condition during the winter and the additional strain of milk production may make matters worse for them. Also, herdsmen are reluctant to hand milk during the bitter cold of winter.

Nonetheless, there is at least one theoretical reason why supplementary feeding over winter is worth further consideration even if milk is not taken from the cows at that time. Interest centres on the possibility that such feeding may improve the condition of the cows and lead to improved calf production, reproductive rate and milk yield in the following warm season. The supplementary feeding carried out experimentally at the Longri Breeding Farm in Sichuan should be seen in that context (Table 6.18).

Table 6.18. Milk yield over a period of 184 days, fat percentage in milk, and weight loss over winter of Maiwa yak cows of three groups: a) fed hay from mid-December to end of April, b) allowed access to conserved grass paddocks from 1 April for 45 days, and c) unsupplemented, control. Least squares means and standard deviations) (Source: Wen Yongli *et al*. 1993)

Year	Treatment group	No. cows	Milk yield (kg)		Fat (%)		No. cows	Weight loss (kg)	
			Mean	SD	Mean	SD		Mean	SD
1989/90	Hay	54	229.0	53.3	6.0	1.3	58	33.5	14.8
	Paddock grass	55	220.6	54.7	5.8	1.6	58	34.5	15.5
	Control	113	218.3	49.9	5.4	1.6	110	35.5	14.5
1990/91	Hay	50	235.4	53.6	5.9	1.3	59	39.9	18.0
	Control	137	224.1	47.6	5.4	1.2	150	42.7	17.4

As seen from Table 6.18, the supplementary feeding appears to have had small but positive effects on milk yield and, unexpectedly (because of the increase in milk yield), on the fat percentage of the milk which is reported to have increased by approximately 0.5 percent (from less than 5.5 percent to nearly 6.0 percent). The estimate of milk yield is derived from measured amounts milked three times per month and does not include, as far as is known, milk sucked by the calves.

The cows given supplements lost slightly less weight over winter than the unsupplemented controls ($P<0.05$). However, the weighing at the end of the winter period was delayed until the end of May, by which time the cows may have started to recover some of their condition, especially because, in 1990, pasture growth at this farm had started exceptionally early. Weight loss alone also does not fully reflect possible changes in body composition, fatness in particular.

Feeding of additive. An imbalance or deficiency of minerals in forages at pasture may limit milk yield of yak. Additives may therefore improve lactating performance of grazing yak. Table 6.19 shows the effect on milk production of a mineral mixture ($CuSO_4 \times 5H_2O$, $ZnSO_4 \times 7H_2O$, $CoCl_2 \times 6H_2O$, $NaCl$, KI, $NaSeO_3$, $CaHPO_4 \times 2H_2O$) (Yuan Youqing, 1994) given as a salt-lick block. The results of such addition during lactation indicate that milk yield of full-lactating yak cows (milking in the year of calving) was increased by 15.5 percent and that of half-lactating cows (those milking into a second season without calving again) by 14.8 percent.

Long Ruijun (1995) has suggested that inorganic phosphate (P) is adequate for grazing yak when a supplement of 0.5 - 1.0 kg of oat hay or highland barley straw was given per day during wintertime.

Data on the effects of individual minerals, including trace elements, on yak productivity are, at present, unavailable. With further investigation, specific trace elements or minerals (or combinations of them) may well be found limiting for yak production as has been found for animal production in other parts of the world.

Table 6.19 Effect of a mixture of mineral additives (provided as a salt block) on monthly milk yield (kg ± SD) of full-lactating and half-lactating cows in different months of the warm season [Source: Yuan Youqing *et al*., 1994]

Lactating type	Treatment	No. cows	May	June	July	Aug.	Sept.	Oct.	Total
Full-lactating	Additive	10	35.0 ±4.2	45.9 ±4.0	60.4 ±4.2	48.9 ±4.3	44.3 ±4.0	36.4 ±4.1	272.1 ±20.2
	Control	10	31.6 ±3.9	41.0 ±4.5	53.7 ±4.0	41.1 ±4.1	36.8 ±4.2	30.5 ±4.0	235.7 ±17.2
	Significance		NS	*	**	**	**	**	**
Half-lactating	Additive	7	29.1 ±3.9	33.3 ±4.0	45.6 ±3.8	40.9 ±3.8	28.5 ±3.5	-	183.5 ±14.1
	Control	7	27.0 ±3.8	29.0 ±3.2	40.5 ±3.2	35.0 ±3.4	23.8 ±2.8	-	159.8 ±13.3
	Significance		NS	*	*	**	**		**

Protein deficiency in forage is potentially one of the most important limiting factors on yak production (especially milk production), and nitrogen supplementation can positively influence the milking performance of cows during lactation. An experiment conducted by Zhang Degang (1998) showed that urea molasses multinutrients block (UMMB) contained 10 percent urea, 0.1 percent mixed minerals and trace elements (Fe, Zn, Mg, Cu, etc.). Given as a supplementary feed (500 g per animal per day) during summertime, it significantly promoted milk yield of Tianzhu White yak and Gannan Black yak in Gansu ($P<0.01$), relative to control groups grazing only.

The yak with UMMB 500 g per day produced an extra 100 g and 160 g milk per day for Tianzhu White yak and Gannan Black yak, respectively. As an alternative protein source, many species of shrubs' leaf are ideal protein supplements for grazing yak due to their high contents in protein (25 - 35 percent) (Long *et al*., 1999b; Dong Shikui *et al*., 2002).

A general comment on the use of feed supplements for yak (already noted in respect of minerals and trace elements) may not be out of place. Many of the yak-rearing areas are remote and this not only increases the costs of supplying supplements (if not locally available) but also there may not be a ready market for extra produce. The main criteria for needing supplements will be unusually poor performance or ill health of the animals, and, when possible, a demonstration of a positive effect from using supplements in that particular situation. The further point about the need for cost-effectiveness has been made before. There is, however, also the other potential use of supplements (for example feed, blocks) as an insurance against the periodic snow disasters during which many yak can die.

Milk production in a second year without calving again

Many yak do not conceive again in the year of calving. It is thus common in yak for lactation to continue into a second year. The amount of milk given over the months from December to May is very low, declining to perhaps as little as 2-4 litres in the whole of April (in one set of observations). Yield then rises with the onset of grass growth and follows a monthly pattern similar to that already seen (cf. Figure 6.3 and Table 6.16), but the amount produced in the second year is approximately half that given in the year of calving (sometimes up to two thirds and sometimes less); hence the name "half-lactating" commonly given to females milking into a second season without calving again - in contrast to the "full-lactating yak" in the year of calving. Parity differences are maintained in the second season at the lower level of yield. The fat percentage in the milk during the second "half-lactating" season is correspondingly higher than in the first "full-lactating" season, in line with the negative correlation between milk yield (quantity) and the fat percentage in the milk.

Factors influencing milk composition

Yak milk is dense and sweetish and greatly liked by the local people. Although its composition varies slightly among different yak breeds at different locations, generally total milk solid (dry matter) content ranges around 15 - 18 percent, fat percentage around 5.5 - 7.0 percent (see also previous Tables), protein and lactose content each around 4 - 5.5 percent, and ash around 0.7 - 0.9 percent during the main lactating period (Table 6.20). The milk solid, fat and protein contents in milk of the yak and its hybrids are far higher than in other cattle, especially dairy breeds, and close to the levels in buffalo (Zhang Rongchang, 1989).

Typically, the proportion of essential to nonessential amino acids is 0.8:1 as observed in a full analysis of amino acids in the milk of the Tianzhu White yak (Zhang Rongchang *et al*., 1986) and 0.79:1, 0.67:1 and 0.72:1 in the milk of the Jiali, Pali and Sibu yak (Ji Qiumei, 2000a).

Milk composition varies with seasonal grass growth and climate change as does milk yield. Milk solids, lactose, protein and amino acids in yak milk are at their highest in mid-lactation and fat percentage increases continuously into late lactation (corresponding also to the changes with season, as shown in Table 6.16). Some relevant results on the Tianzhu White yak (Zhang Rongchang *et al*., 1986) are given in Table 6.21. During the cold season, when milk yield of yak females may be only of the order of 100 g per day, the fat percentage of that milk can be as high as 14 percent. With the growth of forage, protein content in the swards declines from 115 g per kg DM (young grass) to 33g per kg DM (mature grass), and crude fibre in the swards increases correspondingly. The increased crude fibre can offer more acetic acid and butyric acid (the resources of fatty acid) for the mammary gland to synthesize more fat.

Table 6.20 Milk composition and milk yield of different breeds (or yak of countries) at different locations

Breed or yak of country	No.	Milk solid (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)	Milk yield** (kg ± SD)
Tianzhu White	17	16.9	5.5	5.2	5.4	0.77	141.7 ± 43.9
Jiulong	13	17.5	6.9	4.9	4.7	0.82	349.9 ± 131.9
Maiwa	24	17.5	6.3	4.9	5.4	0.82	176.5 ± 64.0
Jiali*	21	16.3	6.8	5.0	3.6	0.95	104.5 ± 31.7
Pali*	22	-	5.9	5.7	3.8	-	236.1 ± 74.9
Sibu*	19	-	7.5	5.3	3.5	-	---
Kyrgyzstan (country)	13	17.4	6.5	5.3	4.6	0.87	630
Nepal (country)	12	17.4	6.5	5.4	4.6	0.90	---
India (country)	14	17.9	6.5	5.9	4.7	0.87	238.4 ± 94.4

* Source from Ji Qiumei et al., 2000a and others from Zhong Guanghaui, 1996b.
** Source from Zhang Rongchang, 1989. (The number of animals shown for milk composition does not apply to milk yield.)

Table 6.21 Composition of milk of ten Tianzhu White yak in Gansu province in three periods of lactation [Source: adapted from Zhang Rongchang *et al*., 1986]

	Early lactation (12 June) (%)	**Mid lactation (25 July) (%)**	**Late lactation (20 Sept.) (%)**
Dry matter	16.1	17.8	16.3
Solids - not-fat	10.9	12.3	10.5
Fat	5.1	5.4	5.8
Protein	5.2	5.7	4.7
Lactose	4.9	5.9	5.0
Ash	0.79	0.75	0.77
Essential amino acid	10.7	11.6	8.1
Nonessential acid	13.7	14.8	9.8
Energy (MJ/kg)	3.5	3.6	3.8

The correlation between the total 184-day milk yield and the average fat percentage was shown to be very small (-0.04) and nonsignificant in a study on 184 Maiwa yak by Wen Yongli and Chen Zhihua (1994) (at the Longri Breeding Farm, referred to a number of times here). This is not a genetic correlation, but suggests nonetheless that if this lack of relationship is confirmed, that milk yield and fat percentage might be more readily improved simultaneously in the yak than is generally the case in dairy cattle.

The yak udder

Yak udders are small and, by the standards of dairy cattle, not well developed. Measurements in Sichuan showed an udder circumference in pluriparous females of 55 cm and an udder depth of between 2 and 3 cm. Sixty females measured in Qinghai (Zang Yinsong, 1985) had an udder circumference of 51.6 cm (SD 12.5), the mammary vein had a diameter of 0.94 cm (SD 0.38), and the teats were 2.2 - 2.3 cm in length and 1.1 - 1.2 cm in diameter. Usually (though not in all studies on the yak) the two rear quarters hold more milk than the two forequarters. The forequarters are generally reckoned to hold about 45 percent of the milk, but other ratios have been reported (e.g. 47.6 percent [Zhang Rongchang *et al.*, 1983] and around 40 percent [Han Zhenkang and Lu Tianshui, 1980]).

The sphincter muscles of the yak's teats are strong and hard squeezing is needed to extract milk. The teats are normally squeezed between the fingers. Especially among Alpine-type yak, some one third of the females are found to have particularly "tense" teats.

In Jiulong county of Sichuan an average yield of 1.4 kg needed almost five minutes of milking time to extract the milk at 80 squeezes per minute - a rate of 0.28 kg per minute (Zhang Rongchang *et al.* [1983] reported a rate of 0.42 kg per min). When a trial with machine milking was conducted, a negative pressure of 400 mm Hg required to extract the yak milk.

Milk let-down

Normally, milk let-down does not immediately follow on squeezing the teats between the fingers, but requires the presence of the calf to jolt the udder and to suckle briefly. If the calf has died, herdsmen place the skin of the dead calf in front of the dam and allow her to smell and lick it, before milk let-down is achieved. Experimentally, the use of a hot towel to massage the udder has been found to stimulate let-down and even to increase yield (Hu Angang *et al*., 1960, unpublished).

The time required to stimulate the udder into let-down was found by Han Zhenkang and Lu Tianshui (1980) to be initially around one minute (SD 15 seconds), but a second, somewhat shorter, period of such stimulation was found usually to be needed in the course of the milking process before all the milk can be extracted. These authors also indicated that the amount of milk in the udder cistern of the yak accounted for only about 6.5 percent of the milk produced at a milking and that the milk produced as a reflex to milking accounted for around 80 percent - of which four fifths was let down as a result of the first stimulation of the udder and the remaining fifth after the second stimulation. Residual milk in the udder (that traditionally obtained by "stripping" in the hand-milking of dairy cattle) accounted for about 13 percent, but this is normally left by the herdsmen for the calf. These authors also found that proportion of milk stored in the udder cistern increased with the parity of the cow to around 10 percent by the fourth parity.

Meat production

Meat from yak is derived from surplus males, often the castrated steers, and also from females, usually at the end of their useful reproductive life, or at the end of their time as milk-producers. In "efficiency" terms (meat output/feed input), the process of meat production in the yak cannot be regarded as "efficient" because, for the most part, the animals are not slaughtered until quite late in life after several cycles of weight gain and weight loss. Meat from the yak represents an important source of sustenance for the herders and their families and an additional source of income from sales. Also, there are circumstances when meat production from yak should be regarded as an efficient use of resources, at high altitudes, that might otherwise not be utilized at all. In this sense, Smirnov *et al.* (1990) pointed out that in a part of the Caucasus, the cost of a unit increase in live weight was ten times greater for beef cattle than for yak. (Yak in the Caucasus fatten on summer pastures at elevations of 3 500 - 4 000 m). In fact, it is claimed that the annual expenditure on keeping a yak was marginally less than that on a sheep. Similar claims of the "efficiency" of yak for meat production are made in other countries and referred to in Chapter 11, part 2.

Meat quantity

The major factor contributing to meat output is the body weight of the animal at the time of slaughter. Thus, the factors associated with variation in growth, discussed earlier in this chapter, all influence the amount of meat produced. Grass growth, as affected by season and location, is the major contributor, along with breed, age and sex of the animal. Seasonal changes in body weight, shown earlier in this chapter, clearly affect meat output. In practice, animals intended for meat are slaughtered, whenever possible, only in the autumn when they are in good, fat condition. Just as July-August are termed by herdsmen concerned with milk as the "golden age", local people regard October as the month of "best fatness" for meat production (in Tibet this is considered to be in September [Ma Zongxiang and Dou Yaozong, 1982]).

Breed and location

There is much variation in the meat properties of different breeds of yak at different locations (as noted earlier, these factors are generally confounded). Meat output in terms of dressing percentage, ratios of lean to bone and loin-eye area are thought to be better from Alpine - than from Plateau-type yak - though this impression may be derived largely from the superiority of the Jiulong breed in Sichuan province. Table 6.22 gives some of the results.

Live weights at slaughter varied with breed and location (and age at slaughter) from 116 - 576 kg. Dressing percentages ranged from 40 - 62 percent. In at least one case (Smirnov *et al*. 1990), the low dressing percentage was attributed to the slaughter of young male yak at what was considered the wrong age - two years old. There was also substantial variation in loin eye area. It should be noted, however, that in some instances the numbers on which the means are based are very small. Most of the information should be regarded as indicative of the range of values found in yak rather than definitive of the merits of any particular class or location of yak.

The question of stage of maturity at time of slaughter is clearly important (some of this information may be available in the source references shown in Table 6.22), but the main criterion for timing the slaughter of yak is usually to leave it to the end of the grass-growing season when the condition of the animals is at its best.

As referred to in Chapter 3, there is interest in the potential benefits of crossing domestic yak with wild yak (by the use of A.I.). Evidence, though not fully consistent across different studies, suggests that the first crosses and backcrosses are heavier and somewhat larger in body dimensions than the domestic yak. Jialin *et al.,* (1998b) reported that meat production of the first crossbred generation was assessed and carcass dissection was made of males. One group (n=14) was slaughtered at six months of age and the second (n=12) at 18 months. Crossbred yak in this study were significantly heavier ($P<0.01$) at 6 months and at 18 months than domesticated ones in the same herd and many of the associated carcass traits were larger in the crosses - but the dressing percentage was similar for both groups of animals (Table 6.23). It would be of interest to know whether the differences between the wild yak crosses and the domestic yak, in terms of meat production, would be maintained to the older slaughter ages more usual in herders' practice.

Effect of sex

As was seen in Table 6.22, there is a tendency for steer yak to have the higher live weights and carcass weights at slaughter relative to females and perhaps higher dressing percentages. However, there is not a consistent finding. Also, a report by Ji Qiumei *et al.* (2000b) indicated that in one of two groups (Jiali yak), dressing percentages and lean/bone ratio were similar in the two sexes and in the other group (Sibu yak) the females were the better in these traits.

Table 6.22 Meat production and carcass attributes of yak from different populations (animals at the age of 6.5 year or older unless otherwise indicated)

Province	Breed or Location#	Altitude (m)	Sex	No.	Live weight (kg.)	Carcass weight (kg.)	Viscera fat % of LW	Dressing percent*	Ratio Lean bone	Loin eye area (sq. cm)	Heart weight % of LW
Sichuan	Jiulong	3 500	Male	2	576	324	1.2	57.6	4.8	87.3	0.58
			Female	2	282	151	2.6	56.2	6.0	58.3	0.71
			Steer	12	496	253	1.8	55.7	4.2	86.7	0.61
	Kangdin-Liuba#	3 500	Steer	25	409	222	2.4	56.6	4.0	86.0	0.46
	Maiwa	3 500	Steer	2	372	208	2.8	58.6	3.0		
			Steer**	4	116	59	1.3	52.1	3.9	31.7	0.59
Gansu	Tianzhu White	3 000	Male	2	288	146	1.3	52.0	2.7		0.63
			Steer	3	262	133	1.7	52.7	3.6	50.3	0.55
	Gannan	3 000	Steer	8	223	112	1.8	51.6	4.1		0.79
Qinghai	Plateau	3 700	Steer	12	368	194	1.6	53.2	4.1	60.6	0.47

	Huanhu	3 000	Steer	5	226	110	1.6	50.3	3.9	66.3	0.57	
	Gangcha#	3 500	Female	11	362	154	1.4	43.9			0.51	
			Steer	17	465	216	1.0	47.5			0.60	
Caucasus (from Tuva)		3 500	Female	3	287	130	3.2	48.6	5.0			
			Male"	3	205	81	0.8	40.3	3.9			
Tibet	Laqu#	4 570	Steer	3	287	170	2.2	61.6			0.61	
	Dangxiong#	4 400	Male	4	264	133	1.1	51.1			0.43	
			Female	2	153	66	1.4	44.2			0.49	
Xinjiang	Bazhou	2 500	Steer**	2	156	72	0.3	46.6	3.7	35.4	0.50	
			Steer***	4	221	123	1.7	57.2	4.2		0.60	
Yunnan	Zhongdian	3 000	Female	2	203	92		32.3	2.8			
			Steer	8	309	179		45.7	4.3			

* Viscera fat included in dressing percentage; ** sterrs of 16-17 months old; " males 2 years old; *** steers 2.5 and 3.5 years old; # location of yak within province.

[Sources: (1) Cai Li *et al.*, 1980b; (2) Chen X. F. *et al.*, 1981; (3) Pu *et al.*, 1987; (4) Research Co-operative Group, 1980-87; (5) Lei, 1983; (6) Smirnov *et al.*, 1990; (7) Jia H. G, 1966; (8) Wei *et al.*, 1981; (9) He *et al.*, 1997]

Table 6.23 Weight and linear measurements of carcass components of crossbred (wild yak crossed with domestic yak) and domestic yak at 6 and 18 months of age [Source: adapted from Jialin *et al.*, 1998b]

	6 months old					**18 months old**				
	Cross-bred		**Domestic**		**Difference**	**Cross-bred**		**Domestic**		**Difference**
	Mean	**SD**	**Mean**	**SD**		**Mean**	**SD**	**Mean**	**SD**	
Sex	4F, 3M		4F, 3M			3F, 3M		3F, 3M		
No.	7		7			6		6		
Live weight (kg)	74.7	10.4	59.8	10.2	14.9**	150.5	56.1	117.7	17.4	32.8**
Carcass weight (kg)	35.4		28.2	5.5	7.2*	71.2	3.0	54.3	8.9	17.0**
Dressing proportion	0.48	0.03	0.47	0.02	0.01	0.47	0.02	0.46	0.02	0.01
Meat weight (kg)	27.1	2.8	21.4	4.2	5.7*	56.1	2.2	42.3	7.5	13.8**
Bone weight	8.2	0.95	6.7	1.1	1.5*	14.6	0.32	12.3	0.11	2.3**

(kg)										
Meat: bone (1) ratio	3.3		3.2			3.6		3.4		
Eye-muscle area (mm^2)	2 070	415	1 644	261	426*	2 914	134	2 520	172	394**
Carcass length (mm)	838	63	734	83	102**	894	46	846	41	49*
Carcass depth (mm)	430	56	377	43	53	582	23	495	31	87*
Carcass chest depth (mm)	453	57	403	49	50	537	18	416	55	120**
Chuck and dorsal meat (kg)	5.3	1.1	4.8	1.7	0.50	10.9	1.8	7.6	0.8	3.3**
Rib weight (kg)	4.3	1.2	3.2	0.39	1.1	4.7	1.4	3.2	1.1	1.5*
Brisket weight (kg)	1.7	0.57	1.1	0.25	0.60	5.7	1.4	4.8	0.90	0.90
Plate weight (kg)	1.7	0.39	1.5	0.48	0.20	3.0	0.68	2.1	0.44	0.90
Shank weight (kg)	2.8	0.20	2.5	0.65	0.30	8.5	1.1	6.7	0.26	1.8*
Loin weight (kg)	3.1	1.1	2.0	0.69	1.1*	8.9	1.6	6.8	3.0	2.1**
Rump weight (kg)	2.7	1.5	1.5	0.39	1.2*	6.7	1.1	4.9	1.3	1.8**
Round weight (kg)	5.5	1.7	4.8	1.5	1.7	9.0	0.86	6.5	1.1	2.5**
Prime cutting yield (kg)	12.3	2.1	9.3	2.4	3.0*	24.5	1.9	18.2	1.1	6.3**
Rate of prime cut	0.35		0.33		0.02	0.34		0.34		0.0

Significant differences: * $P<0.05$; ** $P<0.01$

Effect of age

In a trial in Sichuan province, entire male yak from the age of 1.5 - 4.5 years and thereafter, yak steers to the age of 20.5 years were chosen at random from yak herds in the same area and kept under year-round grazing without supplementary feeding. All the animals were slaughtered at the Animal Husbandry and Veterinary Station in Kangdin county of Sichuan at the end of autumn, in their fattest condition. In spite of the small number of animals involved, the trends shown in Table 6.24 indicate that the dressing percentage increased with age (and live weight) up to six and a half years and declined somewhat thereafter. However, the castration of males after the age of four and a half years and the subsequent switch to steers could be an important factor in the larger increase in dressing percentage noted between the ages of four and a half and five and a half years. Variation among the steers above the age of 16.5 years showed no clear trends (the data for these ages have been pooled).

Table 6.24 Dressing percentage (carcass weight/live weight) of yak males and steers, according to age at slaughter

Age (years)	Sex*	No.	Live weight (kg)	Dressing (%)
1.5	M	2	55	37.6
2.5	M	2	105	44.0
3.5	M	2	182	47.6
4.5	M	2	234	49.6
5.5	S	2	370	55.8
6.5	S	3	401	56.2
7.5	S	4	407	53.9
10.5	S	1	409	51.7
11.5	S	2	417	55.0
14.5	S	3	406	52.3
16.5-20.5**	S	10	413	53.4

* m=entire male s=castrated male (steer)
** Average for the older steers.

Composition of meat

Yak meat is fine textured and scarlet in colour. It is regarded as very palatable, but muscular marbling is poor. It is rich in myoglobins and has a flavour akin to game. Among local people yak meat has been prized above that of ordinary cattle since ancient times. Table 6.25 provides some evidence on composition of the meat for different locations, breeds and ages of yak steers (the rib sample from the Tianzhu White steers was unusually fat).

Table 6.25 Composition of yak steer meat (%) [+SD]

Province / country	Breed or Location	No.	Age (years)	Meat from:	Dry matter	Protein	Fat	Ash	Ca	P	Source
Sichuan	Maiwa	7	1.5	Rib	25.8	21.5	3.3	1.04			Cai Li *et*

				9-11*							*al.*, 1984
Xingjiang	Bazhou	2	2.5	Rib 9-11*	24.7	21.2	2.0	1.07			Wei Ronglu *et al.*, 1981
Gansu	Tianzhu White	3	4.5	Rib 9-10*	33.8	20.0	11.9	0.87	0.02	0.14	Pu Ruitang *et al.*, 1987
				Loin eye	23.7	21.3	1.4	1.05	0.02	0.20	Pu Ruitang *et al.*,1987
Qinghai	Qinghai	?	4.5	Back, rib	25.9	22.1	2.1	1.61	0.03	0.20	Lei Huanzhang *et al.*, 1983
			Over 6	Back, rib	26.8	22.3	2.8	1.68	0.02	0.24	Lei Huanzhang *et al.*, 1983
	Domestic yak*	6	0.5	Rib 9-11	25.8	22.6 ± 1.4	3.3 ± 1.7	1.04 ± 0.6	-	-	Jialin *et al.*, 1998b
		3	1.5	Rib 9-11	31.1	22.6 ± 1.9	7.9 ± 3.7	1.17 ± 0.2	-	-	Jialin *et al.*, 1998b
	Wild yak x domestic yak crosses*	6	0.5	Rib 9-11	27.5	22.7 ± 1.1	3.6 ± 1.3	1.05 ± 0.1	-	-	Jialin *et al.*, 1998b
		3	1.5	Rib 9-11	31.1	22.2 ± 2.2	5.9 ± 2.2	1.09 ± 0.2	-	-	Jialin *et al.*, 1998b
Tibet	Pali	6	Adult	Rib 9-11*	44.1	17.8	25.3	0.84	0.020	-	Ji Qiumei *et al.*, 2000c
				Loin eye	25.8	22.6	2.1	1.03	0.032	-	Ji Qiumei *et al.*, 2000c
Mongolia	Mongolia	?	Adult	Rib 9-11*	27.2	18.8	5.0	0.92	-	-	Zhang Rongchang, 1989

*at Datong Yak Farm ** Source: Research Co-operative Group (report), 1980 - 1987

Besides location, sex, age and breed (if it can be differentiated from location), the rearing treatment of the animals, which is reflected in body condition, must be expected to affect the meat composition of yak. Kirghiz literature cited by Zhang Rongchang (1989) indicates the relationship between rearing treatment and meat composition of yak (Table

6.26). It can be seen that dry matter, fat and energy in yak steer meat increased with the improved feeding level.

Table 6.26 Composition of yak steer meat (percent) under different rearing treatments in Kyrgyzstan [Source: Zhang Rongchang, 1989]

Group	Age (month)	No.	Live weight (kg)	Dressing (%)	Dry matter (%)	Protein (%)	Fat (%)	Ash (%)	Energy (MJ/kg)
I	19	22	234	44.0	26.8	23.0	2.4	1.1	4.9
II	19	22	258	46.3	27.4	22.8	3.6	1.1	5.3
III	19	22	275	49.8	28.9	22.2	5.7	1.0	6.0

* I: suckling the [milked] dam; II: milk with artificial rearing, III: milk with artificial rearing together with supplementation in the cold season.

The amino acid content of meat from different muscles of the yak has been analysed in a number of studies (for example, Zhong Guanghui *et al*., 1993; Mkrtchyan *et al*., 1993; Ji Qiumei *et al*., 2000b, 2000c) The ratio of essential to nonessential amino acids was found to be between 0.6:1 and 0.8:1.

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3 BREEDING, CROSSBREEDING AND HYBRIDIZING OF YAK

Overview

Pure-breeding is the predominant practice with yak. Apart from a scheme involving selection in crossbreds of wild yak with domestic yak in a process of breed development (see Chapter 2), no information has become available on rigorous selection programmes consistently applied for the improvement of the performance of yak in China. However, some selection schemes appear to be under consideration both in China and other countries. The dearth of organized selection schemes is not surprising with an absence of written records of performance and pedigrees and because of the location of yak in harsh environments and remote regions. Herdsmen in some areas, such as those of the Jiulong yak, have a traditional system of selection for replacement bulls. The Jiulong scheme considers the performances of the sires and maternal performance, as well as the physical appearance of the individual. It has to be remembered that the capacity to survive must be one of the chief attributes in the genetic makeup of the yak. This characteristic is likely to be under constant pressure from natural selection.

There is circumstantial evidence that some inbreeding is likely to have occurred with yak as a result of traditional pure-breeding methods and, in some countries, because of insufficient interchange of breeding stock across national boundaries. This can be expected to have harmful effects on the performance of yak.

Crossbreeding among the different types and breeds of yak does not appear to be systematic, but, on theoretical grounds, should be advantageous. Crossing domestic yak with wild yak is receiving widespread attention and favourable results are reported, with indications of heterosis. Crosses of domestic yak with wild yak are also thought to provide a basis for selection in new breed formation (cf. Chapter 2).

Hybridizing of yak with other species of cattle (mainly *Bos taurus* but also *Bos indicus* in some countries) is widely practised. Bulls of local breeds of cattle are used for natural service. But for hybridizing of yak with relatively high-yielding "exotic" breeds of cattle, the use of AI with frozen semen is normal, as the bulls of these breeds have not, in the past, survived for long in the mountainous regions. Hybridizing of yak with cattle is advocated in several countries as a means of increasing milk and meat output from the mountainous regions. Only the first generation of hybrids (F1) is favoured, as later generations of backcrosses have poorer performance (and hybrid males are sterile). However, the F1 females can usefully be mated to males specially chosen for "meat" production. There are both economic and biological limits on the extent to which interspecies hybridization can be carried out. The biological limit is set by the low reproductive rate of yak and by survival rates. A large proportion of the female yak population is required simply to replace the pure-bred yak - even if the size of that population were to remain static and not increase, as seems often desired by herders.

Pure-breeding

Ways of improving yak productivity by selection might be of great importance to the people who depend on yak for their livelihood. As discussed earlier, the yak is the dominant domestic animal in the alpine regions and the mountain plateaux of western China and adjacent areas to the south and north - dominant in economic, though not necessarily in numerical, terms. The yak also has great importance in Mongolia and several other countries (see Chapter 11, part 2). It is an integral component of the socioeconomic system of people in many remote areas and, often along with sheep and goat, it is the main contributor to the livelihood of the herdsmen and their families. And yet, several factors militate against systematic breeding programmes.

The first of these constraints on improvement by genetic selection is that yak are still widely regarded, especially among Tibetan people, as a symbol of wealth. The more yak a family or a village owns, the richer and stronger it is considered to be. To maintain or increase the number of yak can take precedence over improvements in quality, or even overall productivity. Thus, animals are often kept until they die rather than culled for reasons of poor productivity. This can lead to overstocking of pastures and to a potential reduction in the output from the herd as a whole (see Chapters 12 and 13). "Quality" of the herd can become more of a consideration in situations where "competing" families or villages already own similar numbers of animals. Observation also suggests that smaller herds are sometimes of better quality because more pasture resource is available for a given number of animals and greater individual care is given to the animals by the herders.

A second important reason why genetic selection by herdsmen, or by extension officers acting on their behalf, is impeded is the absence of the necessary performance and parentage records - although herdsmen will often claim to know the parents of yak, especially bulls. It is doubtful if the accuracy of this knowledge is ever tested. In some nucleus breeding herds set up recently on the state farms in Qinghai, Tibet, Gansu and Sichuan, pedigrees but not performance were recorded.

Third, survival of the yak in a harsh, even hostile, environment is of paramount importance, perhaps of higher priority than any other single performance trait (though it is unlikely that this matter has been quantified). In terms of selection for survival under these conditions, natural selection is almost certainly more effective than any current procedure devised by man.

In relation to selection for the main products from the yak - milk, meat and fibre - the only convincing evidence of changes resulting from selection applies to fibre, where selection of a "fibre line" in the Jiulong breed appears to have produced far higher yields than in contemporary animals not selected for this trait (Cai Li *et al*., 1980). Because fibre traits are quite strongly inherited and much more so (at least in other species) than milk yield or growth traits, selection progress is relatively easier to achieve with fibre production traits.

The milk yield of yak is very low, relative to other cattle, particularly those specializing in milk production. It has been suggested that the amount of milk produced by yak is only the quantity that would normally be needed to rear its calf. Thus, yak calves that receive only some of their dams' milk, because the rest is taken for human consumption, grow significantly less well (see Chapter 6). An incentive to select for a higher yield in yak is most likely to arise only where there is an expanded market for milk destined for sale.

In respect to meat output from yak, three problems arise that may create conflict with opportunities for selection for growth rate or "size" (meat production), even if these traits were somehow measured. One is the fact that a significant proportion of each year's growth of the animals during the warm season is lost over the period of nutrient deficiency in winter and early spring. This makes it difficult to see what an appropriate selection strategy should be. If the strategy were to be the increase in the size of the adult animal, say at the end of a growing season, the selection process would be delayed to late in life and hence would make slow progress. A second constraint is that when milk is taken from yak for human consumption and the calf is left short, the precise effect on each individual calf is difficult to estimate (even though an average effect of rearing practice is known). And in any case, there is variation in the quantity of milk produced by the dams. Selection among calves for growth rate therefore would be less accurate than in a totally uniform rearing system. A third problem is the opportunistic nature of the disposal of surplus stock that frequently occurs. The lack of a regular marketing strategy for well-grown animals, combined with the relatively rudimentary nature of the current marketing system, particularly in the remote areas, works against selection for "meat".

Nonetheless, in the regions where yak products are in great demand in the marketplace, it seems that herdsmen have acquired both the knowledge and skill to improve production traits - even though it may be done unsystematically and perhaps unconsciously. This is a possible reason why some breeds are held in higher esteem than others. But different breeds are rarely compared with each other in the same place and at the same time. So it is difficult to quantify the extent of any genetic differences in performance of the breeds, as distinct from differences in their looks.

Selection objectives for the chief yak breeds in China

In general, there are no clearly defined breeding objectives and no developed breed structure among herdsmen. Chinese animal scientists, however, decided towards the end of the 1980s to develop breeding objectives for the principal yak breeds. The intention was to provide technical assistance for a more systematic approach to yak breeding and to aim for earlier maturity, to improve the animal's shape for meat production and to develop strains for either milk or meat, or for meat and hair production. The criteria to be adopted therefore stressed body size, growth rate, dressing and meat percentages, milk yield and fat percentage, as well as the yield of hair - both coarse and down, but with an emphasis on the down.

The criteria proposed were approved in Sichuan and Qinghai for the Jiulong, Maiwa, Plateau and Huanhu breeds of yak (Zhong Guanghui *et al*., 1995; Wen Yongli *et al*., 1995) and a corresponding scheme was developed in Gansu for the Tianzhu White breed in 1985 (TAHVS and DAS, 1985). Some information and comments about these schemes appear below, but first though, attention is drawn to a selection procedure used by herdsmen. The procedure in the Jiulong breed is regarded as traditional because it occurred before the advent of the recent provincial schemes and also had particular involvement from the late Professor Cai Li and his colleagues (1980; GAAHB and YRO, 1980a, b).

A "traditional" selection procedure used by herdsmen in the Jiulong area of Sichuan

Selection of yak by the herdsmen in the Jiulong area is relatively systematic. Herdsmen pay more attention to choice of yak bulls for breeding than they do to the cows. The guiding principle for the herdsmen is to check the ancestors (the parents) first and the bull second. Selection of replacement males starts in the herd with calves from cows that have good conformation and high milk yield over two parities of calving. The herdsmen require that the sire of the males being chosen as replacement bulls should have copious hair and a large number of progeny. The bulls being selected should have good conformation. In particular, the herdsmen require that the horns of the selected bulls stretch outward from a rough base and that there is a long distance between the horns. The forehead, head, muzzle and mouth have to be broad; the neck thick and the lips thin and long; withers should be high and brisket wide; the back, loin and rump should be wide and flat; the tail hairy; forelimbs straight and hind legs curved; the scrotum should be shrunken. Acceptable coat colours are black or black with some white specks on the forehead and at the extremities of the body (e.g. legs or tail), but not on the body itself.

It is of interest that selection of bulls in the Jiulong area is made in three stages. The first is a pre-selection at the age of one to one and a half years. There is a second selection from among the first group at the age of three years and a final selection at the age of four to five and a half years. (The relative importance given to different traits at each stage is not specified). Bulls that are culled are castrated and used for meat or draught purposes. After initial mating with cows, bulls that are found to have been defeated in the normal competition for mates, which occurs among the bulls, and males found to have physical defects or bad conformation are then also culled. The herdsmen aim to have two or three successors to an excellent, dominant bull that has been working in the cow herd.

In 1979, in accordance with newly instituted breeding plans, nearly 7 000 reproductive bulls and cows (about a third of the total) were evaluated on physical conformation and body weight (GAAHB and YRO, 1980b). As a result, four adult yak bulls were identified that met or approached the predetermined performance levels. However, by the time the bulls were identified they were too old for use. Clearly, this was an uncertain start to selective breeding and was more akin to a process of population screening (a search for exceptional individuals) than a process of continuous genetic selection. This particular scheme could not be continued, but consideration was subsequently given to selection of yak at various locations and in different counties where the Jiulong yak are kept (Cai Li, 1989). A standardized evaluation scheme for the Jiulong yak was drafted and approved to assist individual evaluation and selection (Zhong Guanghui *et al*., 1995). Finally, a nucleus herd with 412 breeding animals was established in the centre of the Jiulong yak territory and 106 individuals were maintained on a state farm to implement a breed-improvement programme (Lin Xiaowei and Zhong Guanghui, 1998).

The traditional selection methods for Jiulong yak appear to have produced over a period of many decades, perhaps centuries, an improved breed of yak that is highly regarded. Clearly, the criteria applied contain elements that are related to important aspects of production in the yak. However, a cautionary comment should be added, lest it be thought that these methods have to be unreservedly commended because they have tradition and herdsmen's experience on their side. Geneticists would wish to suggest that there is great scope for improving these procedures, even in the absence of sophisticated indices of breeding value and modern computational procedures. To start with, they would ask how closely related the physical appearance of the yak, so much emphasized by the herdsmen, is to actual performance of the herd - in terms of, say, growth, milk yield or reproductive rate. Usually the relationship is not high. A geneticist would also wish to encourage the herdsmen to pay most attention to those characteristics of the yak that provide the greatest economic return irrespective of whether the products from the yak are for home or commercial use. For that reason, it would also be urged that the number of criteria considered for selection be restricted to an essential minimum. Improvement of the important traits is diluted, or even lost, when a lot of attention is paid to less important, even trivial, matters - as may be the case now.

More recent provincial schemes: the example of the Tianzhu White

The Provincial Administration of Standardization in Gansu adopted criteria in 1985 to standardize the assessment of grading for the Tianzhu White yak and to evaluate breeding value as an aid to selection (TAHVS and DAS, 1985; Zhang Rongchang, 1989). The aim was to improve the breed for meat and hair.

Scores are allocated for aspects of general conformation, the body, testes for males and udder for females, legs, feet and the coat. Calves and adults are graded to somewhat different criteria. Weight and height classes are designed according to age and sex of animal and assigned to four grade classes. The use of selected breeding bulls is recommended, and newborn animals may be assigned a grade on the basis of the grades of their parents. Breeding bulls, in turn, are classified into four grades on the basis of the grades attained by their offspring. There are eight nucleus herds with a total of about 400 breeding animals maintained in the central area of this breed and 40 multiplier herds with approximately 20 000 individuals in surrounding areas (Zhang Haimin and Liang Yulin, 1998).

On the face of it, this scheme, like the "traditional" Jiulong scheme, pays considerable attention to aspects of the animals' appearance. This may well detract herders from considering more single-mindedly the performance aspects that matter most, namely, in line with the objectives for this breed, meat and hair production and the underlying factors of reproduction and vigour. Also, as has been found elsewhere with breeding schemes, if too many traits are considered there is a likelihood that none are improved (unless combined in highly sophisticated, statistically complex and computerized schemes).

In spite of reservations about the selection schemes, there appears to have been significant progress in the Tianzhu White yak since the 1980s. For example, the body height of adult breeding bulls and cows older than four and a half years increased from 108.1 cm and 104.3 cm (average of 17 males and 88 females) in 1981 to 110.2 cm and

104.7 cm (20 males and 44 females) in 1987 and to 114 cm and 112.9 cm (98 males and 826 females) in 1997. Corresponding body weights changed for males and females from 189.7 kg and 171.4 kg to 199.2 kg and 179.6 kg and to 202.8 kg and 192.7 kg respectively over those same years (Zhang Rongchang, 1989; Wang Yuchang and Wang Yanhong 1994; Zhang Haimin and Liang Yulin, 1998). However, these data were collected in a simple survey on various farms over a period of years. It is not possible, therefore, to distinguish any contributions from genetic improvement from those in management and feeding (or simply from year effects). There is a presumption, though, that management and feeding practices have remained largely unchanged over this period.

Other schemes

Sarbagishev *et al*. (1989) referred to an organized breeding programme in Kyrgyzstan based on specifications for yak males and females that were concerned primarily with conformation, growth rate and body size. Pedigrees were included and breeding values constructed. The improvement scheme was spread over a number of stock-breeding farms.

But the main scientific effort towards genetic improvement of productivity of yak, in many countries, has been directed at hybridization with *Bos taurus* and, to a lesser extent, *Bos indicus* cattle, rather than to selection. Some consideration has also been given to introducing, by crossbreeding, genes from wild yak into the domestic yak population as a means of improving productivity (see the following section). Lei *et al*. (1994) reported a scheme that uses performance criteria of individual yak and the potential benefits of introducing wild yak.

In the late 1980s, the first Wild Yak Frozen Semen Station was established on the Datong Yak Farm in Qinghai with three wild yak bulls (two captured from the Qilian mountains and one from the Kunlun mountains (Lu Zhonglin and Li Kongliang, 1994; Bo Jialin *et al*., 1998). Another Yak Frozen Semen Station is now in operation at Damxung in Tibet (Zhang Yun, 1994). These are the only A.I. centres in China specific to yak. By 1995, 8 700 crossbred animals of the wild yak with domestic yak had been produced in Qinghai and Gansu that served as the base herds for further selection and breeding of the new improved yak strain of Datong yak (Bo Jialin *et al*., 1998). The scheme used in this development of a "new" breed is described in Chapter 2.

Zhang Yun (1994) reported that there were ten yak bulls from the Sibu and Jiali yak breeds in Tibet and 28 semi-wild yak (F1, or backcrosses) at the Damxung station, though this number had been reduced to 17 in use. At the time of Zhang's report, 50 000 doses of semen had been produced and 2 000 yak cows inseminated - as well as a much larger number of yellow cattle to produce hybrids with the yak.

As yet there is no information on progeny records from these A.I. bulls. The full potential of using such information in selection procedures for improved performance of yak has not yet been realized. However, Zhang also suggested that the distribution of yak semen from this station could play a significant role in counteracting adverse effects of inbreeding, which have been thought to occur in yak in some areas. (The need to introduce yak "blood" from outside sources, to counteract inbreeding in the yak population of different areas, is also referred to by Pal in relation to India [see Chapter 11, part 2].)

Group breeding schemes

Because of the potential advantages of group-breeding schemes in promoting genetic improvement, especially when the participating herds are each relatively small, consideration is being given to setting up such schemes for yak. At present, as far as is known, these remain in the planning stages.

In the early 1990s an "open-nucleus" herd was established at Longri farm in Hongyuan county. This set-up included a small trial to check problems in the recording of accurate pedigrees for purposes of estimating genetic parameters (Zhong Guanghui, 1998). The nucleus herd to promote the improvement of Maiwa yak consists of 12 breeding bulls, tested for their performance, and 180 breeding cows (Lin Xiaowei and Zhong Guanghui, 1998). Records of growth, milk and reproduction have been collected continuously.

Consideration of inbreeding in yak

Inbreeding has harmful effects on nearly all aspects of livestock performance. Inbreeding reduces, for example, reproductive capacity, growth rate, adult size, and milk production and increases mortality, especially among the newborn and young. The amount of harm is usually quite closely related to the degree to which inbreeding occurs. It is a matter that should be considered in relation to yak because the traditional pattern of breeding may encourage inbreeding (cf. Chapter 5). In this system, bulls compete for mates and, in due course, these bulls are often replaced in the hierarchy of the herd by their offspring. This makes it inevitable that some inbreeding occurs. Inbreeding can be much reduced if bulls are exchanged across herds and greater distances - even then the problem may not be avoided but only postponed if two villages, for example, were consistently to exchange breeding stock only with each other. Controlled mating, whereby the herdsman decides on the mates for a particular bull, is similar in that it may reduce or postpone inbreeding, but rarely avoids it for long.

The absence of the pedigrees of animals in yak herds has made it impossible in the past to know the actual extent to which inbreeding has occurred. However, recently, microsatellite markers were used to analyse the genetic structure of different yak breeds/herds in China and other parts of the world and hence to estimate a general inbreeding effect. An assumption is made that the fewer alleles found at any one locus in a breed or herd, the higher will be the degree of inbreeding in that population. These investigations may help clarify the inbreeding issue specific to yak herds or breeds (cf. Chapter 15). However, the actual effects in yak are not known since this requires comparison of the performance of groups differing in their degree of inbreeding. This, in turn, requires performance records linked to pedigrees. For the time being, the probability of harmful consequences of inbreeding in yak is therefore inferred from known, corresponding effects in cattle, sheep and other livestock.

In some countries, such as Bhutan, Nepal and India (see Chapter 11, part 2), concerns about the effects of inbreeding have been expressed by those on the spot. The yak populations in these countries have become relatively closed. This is a consequence of reduced interchange of breeding stock across national boundaries relative to former times that, in turn, increases the likelihood that related animals are mated to each other. The effects of inbreeding must be suspected whenever the general performance of the stock is known, or thought, to have declined relative to an earlier era, and when other systematic changes in husbandry practices, such as overgrazing, for example, cannot account for it. Thus Kozlovskii (1960) stated that yak in the Gorno-Altai region were becoming closely inbred, which, if true, could well account for the earlier view of Denisov (1935) that the yak of that area were inferior, at that time, to those of other regions. Kozlovskii advocated, by way of remedy, the introduction of unrelated yak males and/or of hybridization with other cattle.

Inbreeding occurs whenever animals that are more closely related to each other than "average" are mated to each other. For example, if a son or sons of a popular bull are used in a herd as his replacement, they, in turn, are liable to mate with some of their half-sisters or cousins. Moreover, such bulls are likely to serve other less closely related females, but related through common ancestors more generations back (grandparents or great-grandparents). Mating of full siblings to each other, or parents to their offspring, which is regarded as close inbreeding, can easily occur if steps are not taken to avoid it. Pal *et al*. (1994), writing in relation to yak in India, stated that farmers may use the same male to serve females of two to three successive generations.

Inbreeding also occurs as a consequence of selection, even though selection is widely and correctly advocated and practised for the genetic improvement of livestock. Selection has the inevitable consequence of bringing about an increase in inbreeding, simply as a consequence of restricting the number of animals that become parents of the next generation. The objective in selection schemes must ensure that the beneficial effects of selecting superior stock outweigh the harmful effects of the consequent inbreeding. This consideration is nowadays a routine part of large-scale and long-term breeding plans, such as cattle improvement programmes involving the widespread use of a few bulls through artificial insemination.

The reason for having dealt with the topic of inbreeding at some length is that experience suggests that the effects of inbreeding are easily ignored because they are not readily recognized in the short term. However, the circumstantial evidence for inbreeding is strong in some yak populations, and the potential for inbreeding should not, therefore, be ignored when yak are allowed to mate.

Crossbreeding within the yak species

No systematic crossbreeding appears to be practised among the different breeds or local populations of yak. This is not surprising considering the relative isolation of different communities and the distances separating them. But it is more surprising that it does not seem, so far, to have played more than a minor role in investigations to find out whether hybrid vigour would result from such crossbreeding. There is a likelihood that hybrid vigour would result, although the magnitude cannot be predicted. The likelihood of heterosis from breed crossing can be argued from the relative isolation, over a long time, of discrete populations of domestic yak in different localities and from the likelihood that breeding practices within herds have led to inbreeding (although, again, some would dispute this). Crossing under these circumstances could have merits. From past experiments in China where Jiulong yak and Tianzhu White yak were introduced to other localities for crossing with the local yak, the crosses were at least heavier and larger than the local yak (Ren Chen Luoerri *et al*., 1995; Liang Hongyun *et al*., 1997). However, in the absence of results from the pure-bred animals of the introduced breed in the same locality, it is difficult to know to what extent this improvement represents the effects of heterosis or the consequence of bringing in "superior" genes from the new breed. Table 3.1 gives some of these results for crosses with the Jiulong yak.

Table 3.1 Improvement of the yak in Luhuo county in Sichuan by crossing with the Jiulong yak [Source: Zhong Jincheng, 1996]

Type	**Age (year)**	**Sex**	**No.**	**Average body weight (kg)**	**Average body measurements (cm)**		
					Height	**Length**	**Heart girth**
F1 (Jiulong crossed with local)	Birth	M	10	13.8	54.4	48.1	57.6
		F	12	13.2	54.4	49.2	56.8
	0.5	M	8	46.9	71.0	77.4	89.7
		F	10	41.5	68.4	73.6	86.2
	1.0	M	8	85.0	95.7	107.7	127.3
		F	8	80.2	90.3	103.3	122.7
Local Luhuo yak	Birth	M	6	11.9	53.5	46.3	56.2
		F	6	11.0	51.6	46.0	54.0
	0.5	M	6	36.6	66.3	69.3	82.0
		F	4	29.9	63.3	67.8	81.3
	1.0	M	3	81.3	85.0	93.3	109.3
		F	3	77.8	80.3	90.7	106.0

Further support for the potential usefulness of crossbreeding comes from the attention paid more recently to crossing of domestic yak with wild yak and the claims of improved performance from such crossbreeding.

In the results presented from such trials, it is also not possible to differentiate clearly between the additive genetic effects (e.g. the fact that wild yak are larger than domestic yak) and the occurrence and magnitude of heterosis as a result of the crossing; but some results from such crosses are shown in Table 3.4.

Size of pure wild yak

Measurements were made in the 1960s on five adult male wild yak by the Agriculture and Animal Husbandry Department of Tibetan government (Study Group [Qiangtang], 1978). These animals had been caught in the Qiangtang area of northern Tibet. Their measurements are shown in Table 3.2.

Table 3.2 Body dimensions and weight of five male wild yak from Tibet

Body dimensions (cm), weight (kg)	Average	Range
Head length	61.1	(55 - 67)
Forehead width	27.3	(26 - 32)
Circumference of base of horn		(30 - 40)
Body length	179.3	(171 - 193)
Height at withers	158.8	(152 - 163)
Heart girth	240.6	(218 - 264)
Chest depth	91.1	(90 - 92)
Chest width	61.6	(53 - 78)
Cannon bone circumference		(22 - 24)
Estimated body weight	1 000.0	

Some wild yak calves caught by staff of the Animal Husbandry Institute of the Yushu Tibetan autonomous prefecture of Qinghai province were compared with domestic yak calves under the same conditions of feeding and management (Xu Guilin, 1985). Table 3.3 shows the weights and weight gains of the two groups. It can be seen from these results that the wild yak calves were 86 percent heavier than the domestic yak calves at three months of age but, relative to their weight, grew more slowly (though not necessarily less in absolute terms) so that by the age of 16 months the wild yak were only 63 percent heavier than the domestic ones.

Table 3.3 A comparison of the body weights and weight gains at various ages of five wild yak and 19 domestic yak kept under the same conditions of feeding and management [Source: Xu Guilin, 1985]

Age (months)		3	4	5	6	12	16
Domestic yak	Weight	33.6	39.2	48.2	51.5	59.1	67.4

	gain (kg)	5.6	9.0	3.3	7.6	8.3	
Wild yak	Weight	62.5	71.9	77.3	81.5	92.5	110.1
	gain (kg)	9.4	5.4	4.2	11.0	17.6	

Crossbreeding of wild yak with domestic yak

Some results from the crossing of wild yak with domestic yak are available. Provided the progeny from such crosses of domestic with wild yak have not been given preferential treatment over the domestic yak alongside them (and that may be a matter in question), the results suggest that the crosses have an advantage. Lu Hongji *et al*. (1987), for example, showed that the birth weight of crosses between domestic and wild yak were more than 30 percent heavier at birth than domestic yak calves. By age six months, the advantage in favour of the cross had increased to more than 50 percent. Calves with only one quarter wild-yak blood were 16 percent and 35 percent heavier at birth and six months of age, respectively.

Staff at the Lanzhou Institute of Animal Husbandry and Veterinary Science of the Chinese Academy of Sciences used some frozen wild yak semen to inseminate female domestic yak on the Datong Yak Farm of Qinghai province (Lu Hongji *et al*., 1987). They also produced some backcrosses of the F1 to local domestic yak (to produce 0.25 percent wild yak) and mated some local domestic yak to males of the Jiulong (domestic) breed of yak (cf. Chapter 2, Datong breed). The results are shown in Table 3.4 and suggest that crossing to the wild yak increased body weights and weight gains over the first six months of life. These weight gains were greater, relative to the birth weights, in the crosses with wild yak than in crosses with the Jiulong. The local domestic yak showed the lowest relative weight gains to six months old. There were no measurements beyond that age. Some of the wild-domestic crossbred yak at the Datong farm are illustrated in Figure 3.1.

Table 3.4 Body weights (kg ± SD) of local domestic yak and crosses with Jiulong yak and wild yak [Source: Lu Hongji *et al*., 1987]

	Type of calf			
	Local yak	**Local x Jiulong (F1)**	**Local x F1 (wild) (25% wild)**	**Local x wild yak (F1)**
Birth weight	13.2 ± 2.3 (n = 25)	14.0 (n = 2)	15.3 ± 1.9 (n = 76)	17.3 ± 2.3 (n = 77)
6-month weight	65.2 ± 10.5 (n = 64)	73.7 ± 6.9 (n = 9)	86.1 ± 4.6 (n=21)	101.3 ± 9.4 (n = 33)

In the 1990s, there was intensive use in Qinghai of the wild yak semen by A.I., or the use of semi-wild yak bulls with natural mating, to try to improve the domestic yak productivity and "rejuvenate" the yak population. Some comparable data from observations of the F1 (half wild yak blood), B1 (one quarter wild yak blood) and local yak under the same feeding and management system in southern Qinghai are shown in Table 3.5 (Yan Shoudong, 1998). It was found that the body measurements and weights of the semi- (F1) and quarter-wild yak (B1) were higher than those of domestic yak within the same age groups. As seen from Table 3.5, birth weight, height, length and heart girth of the F1 were greater than of the domestic yak calves and particularly at 18 months old, the measurements of both the F1 and the B1 were greater than of domestic yak.

Interest in the use of the wild yak to improve production of domestic yak was exemplified by the presentation of a number of papers on this topic at the first, second and third international congresses on yak, held in China in 1994, 1997 and 2000 (Zhang Rongchang *et al*., 1994; Yang Rongzhen *et al*., 1997a; Han Jianlin *et al*., 2002; Zhao Bingyao and Zhang Jianwen, 1994). It was noted in those papers that, historically, herdsmen in the Gannan area of Gansu drove their domestic yak females into regions where wild yak lived, in order to allow natural mating with wild yak bulls. The crossbred progeny would later be selected to improve the domestic yak population. Based on this popular experience, more systematic studies using frozen semen from wild yak bulls are in progress. Substantial numbers of first-cross and backcross (25 percent wild yak) offspring have been born and are reported to grow significantly larger than the local domestic yak. The benefits of wild yak blood, as noted in these studies, have also carried over into crossing with the local yellow cattle. When yak bulls that had 50 percent wild yak blood were mated to yellow cattle, the resulting F1 hybrids were of the order of 20 percent larger at six months old than comparable F1 hybrids of yellow cattle with domestic yak. Yang *et al*. (1997b), Lu and Zhao (1997), Yan Shoudong (2002) and Amarsanaa *et al*. (2002) presented similar findings using wild yak to increase the growth and the related meat production of the domestic yak.

It is not known, from any of the studies previously referred to, what is the relative importance of the role of heterosis and of the additive genetic contribution from the wild yak to its cross with the domestic yak, as discussed earlier in relation to crosses among domestic breeds of yak.

Results of studies in another area of Gansu (Lu Zhonglin and Li Kongliang, 1994) suggested that substantial increases in body size, hair production and meat output were achieved in first crosses of wild with domestic yak, relative to the latter. Milk yield was found to have increased by more than 10 percent. Yan Ping *et al*. (1994) reported, more specifically, that the fleece weight of adult females was 1.76 kg, 1.65 kg and 1.47 kg for half-wild, quarter-wild and domestic yak, respectively. These authors also found that, importantly, the proportion of the undercoat was increased substantially with the introduction of wild yak blood - but the strength of the fibres was not affected. The use of wild yak to improve domestic yak performance through a process of crossing and selection was also reported to be under investigation in Qinghai (*Lei Huanzhang et* al., 1994).

But clearly, only the additive genetic contribution from the wild yak genes will be useful in the actual process of subsequent selection (though the cross will retain some of the advantages from the initial heterosis). It is the perceived advantages of the introduction of wild yak blood into domestic yak populations that led to a project to develop a new breed from such a crossbred foundation (see Chapter 2).

Breed conservation

Taking into account the size of the present domestic yak population as a whole, it would be difficult to argue that conservation measures are a matter of urgency at this time. This might change if social or economic pressures were to reduce the extent of yak keeping - as is already evident in some areas, such as Nepal - or if predicted changes in global climate (over decades and centuries) have the effect of restricting the future distribution and size of the yak population.

Preservation of some of the remarkable traits of the yak in terms of its adaptation to a harsh environment and to long periods of severe deprivation should, nonetheless, be of interest to animal breeders worldwide. There are parts of the world where these characteristics could assist in establishing animal production and other parts where such resilience, on the part of the animal, could lead to better utilization of natural resources. Currently, however, the gene pool of the domestic yak as a whole is not endangered.

A different situation seems to exist for some of the more localized, and to an extent differentiated, populations or breeds of yak. The total numbers in some of these breeds is not large and hybridization with *Bos taurus* and *Bos indicus* cattle further reduces the proportion of the yak population available for its replacement.

For example, the Jiulong yak, possibly the best producer among the yak breeds, numbers 50 000 animals (Zhong Jincheng, 1996; Lin Xiaowei and Zhong Guanghui, 1998). The total numbers, however, tell only a small part of the story. Starting from a small herd, the Jiulong breed of yak has been a closed population for hundreds of years. Throughout the breed's history, herdsmen are said to have avoided introducing outside blood. Moreover, the system of selection practised by the herdsmen (previously described), and the natural competition among bulls for dominance makes it virtually certain that the effective size of the population is small and that inbreeding occurs (though the extent of this is a matter for debate). Thus, if the particular properties of the Jiulong are worth preserving and are not to be lost through genetic drift, special measures may be required. This was recognized by Chinese experts some years ago and led to the setting up of a random-breeding herd of 100 yak females and 20 males maintained per generation (Zhong Jincheng, 1996).

Table 3.5 Body weight and measurements of F1 and B1 of wild yak crossed with domestic yak in southern Qinghai [Source: Yan Shoudong, 1998]

Group	Sex	Age	No.	Height	Length	Heart	Cannon bone	Body

		(month)		(cm)	(cm)	girth (cm)	Circumference (cm)	Weight (kg)
F1	m	At birth	21	56.1 ± 3.4	52.3 ± 4.6	59.6 ± 4.6	8.10 ± 0.38	14.9 ± 1.8
	m	6	19	80.8 ± 6.0	81.8 ± 7.5	94.3 ± 7.3	9.74 ± 0.42	49.6 ± 6.7
	m	12	11	80.7 ± 4.4	82.6 ± 6.7	92.5 ± 7.3	10.23 ± 0.61	45.9 ± 7.2
	m	18	13	91.8 ± 6.4	96.5 ± 8.7	117.5 ± 9.4	11.85 ± 0.83	98.9 ± 27.8
	f	At birth	31	56.2 ± 3.7	52.5 ± 5.2	59.6 ± 3.8	8.10 ± 0.57	14.6 ± 2.3
	f	6	30	79.3 ± 5.7	80.8 ± 9.0	93.1 ± 8.3	9.62 ± 0.68	45.8 ± 9.0
	f	12	20	81.6 ± 6.3	81.7 ± 8.6	97.6 ± 8.0	10.30 ± 0.64	49.4 ± 8.9
	f	18	19	90.0 ± 3.9	94.6 ± 11.6	114.6 ± 6.2	11.84 ± 0.67	90.9 ± 22.5
B1	m	At birth	41	55.2 ± 4.3	51.2 ± 4.4	59.8 ± 7.2	8.27 ± 0.39	14.8 ± 2.5
	m	6	39	78.1 ± 7.5	78.5 ± 7.3	94.2 ± 10.4	10.18 ± 1.33	50.7 ± 13.7
	m	12	20	83.5 ± 7.8	85.0 ± 8.7	98.6 ± 8.8	10.30 ± 1.49	54.5 ± 13.5
	m	18	23	92.8 ± 7.3	97.3 ± 10.0	115.9 ± 7.7	11.48 ± 0.72	95.7 ± 23.2
	f	At birth	64	54.6 ± 3.4	51.5 ± 4.4	58.7 ± 4.5	7.89 ± 0.66	14.7 ± 2.6
	f	6	64	77.3 ± 7.4	77.2 ± 7.9	92.7 ± 9.6	9.86 ± 0.97	47.9 ± 13.0
	f	12	37	82.2 ± 5.3	83.7 ± 7.3	99.3 ± 8.2	10.49 ± 0.80	54.7 ± 10.1
	f	18	37	91.4 ± 6.0	96.3 ± 7.9	116.3 ± 6.8	11.62 ± 0.87	94.3 ± 15.4
Domestic yak	m	At birth	81	53.1 ± 4.1	48.8 ± 4.0	57.5 ± 3.9	7.83 ± 0.63	13.6 ± 2.3
	m	6	76	77.4 ± 5.2	79.5 ± 8.1	92.8 ± 7.1	9.18 ± 0.71	48.1 ± 9.4
	m	12	50	80.9 ± 5.0	81.8 ± 5.9	97.8 ± 7.8	10.34 ± 0.73	53.6 ± 10.0

	m	18	49	89.7 ± 5.4	94.3 ± 8.0	113.6 ± 7.8	11.44 ± 0.90	88.7 ± 19.6
	f	At birth	92	52.8 ± 3.8	47.9 ± 4.0	56.8 ± 4.0	7.58 ± 0.54	12.9 ± 2.1
	f	6	88	76.6 ± 6.3	79.7 ± 6.5	93.6 ± 7.2	9.62 ± 0.78	48.1 ± 9.5
	f	12	66	81.2 ± 6.0	82.1 ± 6.4	97.9 ± 6.9	10.20 ± 0.86	51.5 ± 9.5
	f	18	62	89.6 ± 5.6	94.4 ± 8.1	114.8 ± 8.2	11.47 ± 0.96	93.2 ± 21.0

This was managed in the Hongba area of Jiulong county and was the responsibility of the Animal Husbandry Station there. Income from the sale of milk and culled animals met some of the costs. There was also a subsidy from local government to assist the project. This type of approach is clearly commendable as one way forward in terms of breed conservation. A random-breeding herd has, however, a further potential advantage in that it can also serve as a yardstick against which to measure progress from any genetic selection in other parts of the breed population.

Other yak breeds may be in a similar situation to the Jiulong, with total numbers not large and the size of the "effective" breeding population possibly quite small. The Tianzhu White breed, in an area of Gansu province, could be one and its conservation is being considered (Wang Yuchang and Wang Yanhong, 1994). Zhang Haimin and Liang Yulin (1998) indicated that the number and proportion of the pure white yak in Tianzhu have increased as a result of the protection programs; for example, in 1952, the proportion of pure white animals was 20.3 percent and in 1981 it was 31.5 percent. It increased to 44 percent in 1998. Interestingly, the price of a white tail was double that of a black one in 1998 (120 yuan per kg compared to 60 yuan per kg).

Local breeds may have special merits or special characteristics that could be lost in the absence of positive action to maintain such breeds. Investigation of the need for conservation in the yak should therefore receive some attention even if local rather than general action may be called for. A useful start might be an up-to-date census of the yak population, its various types and breeds and current breeding practices. In combination, such information would help to indicate the (genetically) effective size of the different breeding populations, both in China and elsewhere. A census of numbers alone, as regularly practised in some countries such as Mongolia, though helpful, is not enough for this particular purpose.

Too often in matters of conservation, action has been delayed until damage to the breed, or even extinction of the species, has become imminent. This must not be allowed to happen with the yak.

The genetic approaches using chromosomal and protein polymorphisms, mitochondrial DNA RFLP and sequencing, and microsatellite genotyping (referred to in Chapter 2) to estimate genetic distances among breeds should go some way towards determining priorities for breed conservation (Han Jianlin, 1996, 2000). (The technology is discussed in more detail in Chapter 15).

For the wild yak, it is widely accepted that conservation is a matter of importance and urgency. Accounts, from as recently as the nineteenth century, testified to vast herds of wild yak in the Kunlun mountains of Tibet and Qinghai. These are no longer seen. Miller *et al*. (1994) estimated that wild yak of all ages and both sexes may still have numbered around 15 000 in the early 1990s, and this is also the number quoted more recently by Schaller (1998). Miller and Schaller (1996) claimed an estimated 7 000 - 7 500 wild yak remained in the Chang Tang Wildlife Reserve in Tibet at the time of their survey. But this number does not necessarily give an accurate picture of the threat confronting this wild species. Wild yak in China are included in the country's wildlife-protection legislation, but, according to Miller *et al*. (1994), the Departments concerned have inadequate resources for enforcement. The factors that have led to a dramatic decline in wild yak numbers over the past century still operate, even if to a lesser extent. These factors include excessive hunting, partly for food, the encroachment of the infrastructure of modern society, such as roads, and the increasing competition for grazing land from domestic livestock (Miller *et al*., 1994).

Hybridization of yak with cattle of other species

Ancient documents show that yak have been hybridized with ordinary cattle (*Bos taurus*) for at least 3 000 years. Documents from the eleventh century China, in the Zhou dynasty, suggest that hybridization of yak with cattle by the Qiang people gave benefits that nowadays would be called heterosis (or hybrid vigour). The name *Pian Niu* and variants of it have been used for these hybrids from earliest times (Ceng Wenqiong and Chen Yishi, 1980; Xie Chenxia, 1985; Cai Li, 1989). However, many other names exist (see section on local names). In some areas, such as northern India, Nepal and Bhutan, hybridizing with *Bos indicus* cattle also occurs.

Systematic hybridization of yak with other cattle has been recommended and practised for many years - and certainly as long as hybridization by plant breeders has been in fashion. The hybrids find a special niche with herdsmen in providing extra milk and as draught animals, usually at somewhat lower altitudes than the typical yak country. Hybridization is carried out primarily with yak females mated to bulls of local cattle.

This is regarded as the normal hybridization and, in China the F1 is called "true *Pian Niu*" (or simply *Pian Niu*). The reciprocal hybridization of female cattle to yak bulls is also practised and regarded as "counter-hybridization" with the progeny called "false *Pian Niu*" (see Figure 3.2) and many other local names.

The hybrids are always mated back to either yak or cattle males. There is no alternative to this as the F1 males are sterile. The herdsmen use, for the most part, the cattle available to them in their area; in China, for example, they are the local, so-called "yellow cattle". The hybrid progeny of the F1 generation are then called "local *Pian Niu*". However, much investigation has gone into the use of "improved" breeds of cattle of dairy, beef and dual-purpose types. Results of hybridizing with both local and "improved" cattle breeds are given in Chapter 7. The name that is given to the first hybridizing of yak with "improved" cattle breeds is "improved *Pian Niu*" - in order to distinguish it from the "local *Pian Niu*".

Information on the production of hybrids between yak and cattle will also be found in Chapter 11 in relation to individual countries.

In the course of experiments in the 1920s and 1930s at Buffalo Park, Wainwright, Canada, aimed at developing a meat animal for the cold northern regions, including Alaska, a small number of hybrids were also successfully produced between yak (male) and female American bison and half-bison (bison crossed with a cattle cross) (Deakin *et al*., 1935).

Figure 3.1 Pian Niu female (F1 from yak dam and local, yellow cattle sire)

Figure 3.2 "False" Pian Niu female (F1 from local, yellow cattle dam and yak sire)

Local names for hybrids

Names for the first generation hybrids of yak and cattle include the name *dzo* in Tibetan areas, variants of which extend into Mongolia and other countries, and *chauri*, the name used in Nepal. The various types of backcross hybrid, both to cattle and to yak, have an especially rich variety of names that differ in different parts of China and elsewhere. Descriptions of these names have been given by, among others, Zhao Zhengrong (1957), Hu Angang *et al*. (1960), Cai Li (1980), Joshi (1982), Zhang Rongchang (1989) and Pal (1993). The uninitiated traveller may find himself confused by the fact that the local people in China are said to call the hybrids of yak with cattle "improved cattle" - this usage is avoided here.

Distribution of hybrids

In the areas of the Henduan Alpine type of pasture, hybridizing of yak females with cattle males is not widely practised, nor is interspecies hybridization common in the pastoral regions at high elevation to which cattle cannot adapt. Such hybridization is, however, widespread in areas of mixed pastoral and agricultural production at lower altitudes. Table 3.6 shows, by way of example, the relative proportions of pure yak to hybrids and yellow cattle in two such areas in Sichuan. In the main yak-producing areas, hybridization with cattle is normally restricted to only a small proportion of the yak herd (see section, Limits to hybridization).

Nomenclature

Because of the diversity of local names for different stages of hybridizing and in order to avoid confusion in the presentation of results in this and later chapters, the scientifically more formal nomenclature of F1 (first-generation hybrids), and B1 (backcrosses), etc. will be used. It should be noted that in publications from China and some other countries, the backcross-hybrid generations are often denoted as F2, F3, F4, etc. This nomenclature will not be used here as it also could lead to confusion among readers, geneticists in particular, who will be accustomed to these notations denoting successive generations of crosses (or hybrids) mated among themselves. Backcross hybrids will be described here by the letter B, with a number denoting the generation and a letter to show whether the last male used was cattle or yak - when that has been specified. (Thus, B1(C) would denote a backcross-hybrid animal produced from the mating of a F1 female to a cattle bull, etc.). In the same way, in cases where doubt could arise, the F1 generation will indicate whether the sire was a cattle breed or a yak.

Table 3.6 Proportions of yak, *Bos taurus* cattle and hybrids in Ganzi county of Sichuan

Type	Pastoral area (%)	Agricultural area (%)
Yak	91.4	16.8
F1	7.8	55.8
B1(C)	0.7	3.7

Cattle	<0.1	21.9
Total No.	41 541	25 560

The hybrid females are an important source of milk and milk products, for home consumption or for sale, and the males, since they cannot be used for breeding, are used for draught purposes, or are slaughtered for meat (see Chapter 7).

In China, the reciprocal hybridization procedure between yak bulls and yellow cattle females is carried out mainly in the cattle-producing areas of the cold Minshan mountains, especially in the Min county of Gansu province and Pingwu county in Sichuan province. These hybrids do not give much milk and are used mainly for draught purposes.

Hybridization policy

The first generation of hybrids of yak and "ordinary" cattle adapt well to the conditions in which they are used. They have some of the good characteristics of both parental types: resistance to a harsh environment from the yak and extra productivity, milk in particular (but with a lower fat percentage), from the cattle. Backcross hybrids to cattle, however, are less well adapted to the environment, and their productivity is often little better than that of yak - most probably through loss of heterosis (although there is no strict quantification of this). Backcross hybrids to cattle are not therefore favoured - one practice being to dispose of these hybrid calves immediately after birth, in order to have all the milk from the dam available for use or sale by the herders.

The alternative of backcrossing to the yak does, however, provide a particularly good source of animals for meat production. This system is encouraged and practised in China and elsewhere.

Cai Li *et al*. (YRO and XLF, 1983; YRO and GISP, 1984) showed, from a comparison of two neighbouring and otherwise similar grassland farms in Sichuan, that the output per head of animal, per unit of land and per unit of labour can be seriously reduced if the proportion of B1 hybrids is allowed to become too high. On the Xiangdong Livestock Farm, the proportion of B1 hybrids was not allowed to exceed 5 percent of the total herd and some selection was practised of those retained. On the other farm, Axi Livestock farm, the backcross progeny of the F1 hybrid generation were retained in full. The results of the comparison are shown in Table 3.7.

The use of "improved" breeds.

In China, starting at Datong in Qinghai province around 1939 and in the area now known as the Ganzi Tibetan autonomous prefecture in Sichuan from 1941, some yak were crossed with Dutch Holstein-Friesian bulls. Such hybridization did not become systematic until the mid-1950s when 200 bulls of various breeds were introduced to the yak-producing areas of China (Zhang Rongchang, 1989). The breeds included the

Holstein-Friesian, Shorthorn, Simmental; Latvia, Ala-Tau, Kostrome cattle, the Mongolian, Binzhou, Sanhe, Qinchuan, Yinging and others. More recently, Charolais, Hereford, Limousine and others have been added to those available for hybridizing with yak. Mating was tried initially by natural mating, but artificial insemination was also used and continues as the predominant practice (Cai Li, 1989; Zhang Rongchang, 1989). From 1979 to 1985, a yak research team coordinated the hybridizing with such exotic breeds in the five principal provinces with yak in China, and some 32 000 hybrids were produced. As so often happens with fieldwork, relatively little of this work has provided comparative performance results - those available are quoted in Chapter 7.

Table 3.7 Comparison of output of animal products from two neighbouring and similar farms in pastoral areas of Sichuan province (1977 - 1981)

	Xiangdong	**Axi**
Total stock	2721	4346
Yak (%)	69.7	31.5
F1 (%)	25.4	21.1
B1 hybrids* (%)	4.7	47.1
Ordinary cattle (%)	0.2	0.3
Output value** of:		
Milk	49 673	64 565
Cheese	2 405	2 931
Hide	1 753	1 789
Hair and down	1 914	1 258
Market animals	38 760	54 825
Total value	***94 505***	***125 368***
Average output per:		
Head of stock	34.7	28.9
Head of staff	716	412.4
6.7 ha grassland	92.8	53.5

* B1 hybrids here are mostly backcrosses to cattle bulls - very few to yak.
** Output value (yuan; US$1=1.7 yuan) as the mean of 1979 - 1981 calculated according to fixed prices in 1980 as follows: milk 0.33 yuan/kg; cheese 0.56 yuan/kg; hide 8.9 yuan each; hair and down 1.74 yuan/kg; market cattle 85 yuan/head.

To better exploit the advantages of hybridization while avoiding the reproductive problems caused by using large "exotic" bulls, an alternative has been devised in parts of China whereby crossbred cattle, instead of large exotic breeds, are hybridized with the yak. For example, the Holstein Friesian or Simmental breed was used to produce F1 breeding bulls by crossing them first, by A.I., with the local cattle. The F1 crossbred bulls, with their relatively smaller body size, were then used on the yak to produce a hybrid F1 through natural mating.

Although the growth and performance of the hybrids for both milk and meat production was highly regarded (see Chapter 7, for performance results) the bulls of these various "improved" breeds (and 75 percent grade bulls of these breeds with yellow cattle) did not adapt to the local conditions and high altitudes in China. Most of the bulls died of mountain sickness or for other reasons within two years of introduction, and many died within the first few months. The bulls introduced in the mid- and late 1950s left fewer than 1 000 F1 and B1 hybrid progeny over a more than 20-year period.

Hybridization of yak with these "improved" breeds of cattle is now carried out by A.I. with frozen semen. This procedure inevitably restricts the utilization of these breeds to the more accessible and well-organized yak herds. In practice in many areas, therefore, the *Bos taurus* (and *Bos indicus*) cattle used for hybridizing with the yak will continue to be the local types of cattle.

Hybridization of yak with "exotic" breeds of cattle has also been practised in other countries for a long time (see Chapter 11, part 2), such as in as, some countries of the former USSR. Thus, Denisov (1938) reported on hybrids of yak and Schwyz (Brown Swiss) cattle, and more recently Katzina *et al*. (1994) added the Jersey and the Galloway and a continuing use of the Schwyz (now of American origin, hence probably the American Brown Swiss) to the list of exotic breeds referred to previously. Several of the breeds referred to are also used in Mongolia (Zagdsuren, 1994).

Limits to hybridization

The relatively low reproductive rate of the yak sets severe limits on the proportion of the female yak population that can be used for hybridizing with cattle if the numbers of the pure yak population are to be maintained, or possibly increased. In practice, it has been found best to restrict production of hybrids to the F1 generation only (whose offspring, in turn, are then slaughtered for meat). The male sterility of the hybrids prevents *inter-se* crossing systems and allows only the mating of the F1 hybrid back to yak or cattle bulls. Reduced productivity, relative to the F1, makes the B1 and later backcross generations unattractive commercially.

The actual proportion of the female yak population that can be hybridized with cattle depends on the reproductive rate, the replacement rate for cows (depending on the rate of death and disposal of the cows) and the loss of female calves before they reach reproductive age. These factors will vary from region to region and from year to year.

If it were assumed that:

- the yak population remained static in numbers,
- an average reproductive rate for the yak cow is around of 0.5 (equivalent to a live calf every second year),

- 10 percent of cows are eliminated annually and
- 10 percent of calves are lost before breeding age,

then 50 percent of the yak cow population could be available for hybridization. (These assumptions are equivalent, on average, to a yak cow producing, in her lifetime, two female progeny that survive to breeding age.) Any intention to expand the yak population would reduce the proportion that could be hybridized. If an increase of 10 percent in population numbers were required (and, as indicated earlier, herdsmen like to increase the number of animals they own), then only 10 percent of the yak cows could be hybridized with cattle - when the other assumptions remain the same.

Other assumptions would be entirely reasonable. Thus, higher replacement rates for cows and poorer survival of calves would reduce the proportion of yak females available for hybridization. For example, if replacement rates for cows and mortality among calves were both as high as 20 percent, as happens in some situations and some years, no yak cows would be available for hybridization if the reproductive rate of the yak did not exceed 50 percent - even with a static yak population. Matters would be even worse if snow disasters strike in particular years and localities and the rebuilding of the pure yak population becomes the top priority. On the other hand, in some regions and countries, where reproductive rate over a lifetime of the yak may be higher than in the examples given, the proportion of the yak female population available for hybridization can be increased.

The precise proportions of the yak population available for hybridization thus depend on the circumstances in any particular herd or group of herds. The point has been made often (see also Chapter 7) that the production of yak-cattle hybrids can play a useful role in improving the economics of animal production in the mountainous regions and particularly at the lower elevations of the yak territory and in the proximity to markets where the extra produce can be sold. But it also needs to be said that such hybridization is not a panacea. The pure yak must, perforce, remain the major proportion of the total bovine population in the mountainous regions. The attractions of hybridizing yak with cattle should not be allowed to detract from the need to consider genetic and husbandry improvements for the yak itself. In fact, improvements in the productivity and reproductive rate of the yak would also in turn increase the opportunities for hybridizing of yak with cattle, as already apparent in some areas.

There is clearly an opportunity to produce additional hybrids from the reverse process, that of mating cows of other local, domestic cattle species to yak bulls or using the semen of yak for insemination - although it appears that this hybrid (the "false *Pian Niu*") is traditionally used mainly for ploughing (see Chapter 7). This process also depends on having available a reproductive surplus in the cattle population.

Recently, Professor Jack Rutledge (personal communication, 2002) made a technology-based proposal for trials to produce hybrids from "improved" (e.g. Holstein) cattle and yak by *in vitro* production of embryos - using oocytes from slaughter cattle and yak semen. The resulting embryos then need recipient dams for their further development to birth. This proposal was conceived in the context of a situation (in a part of the Andes) where such hybrids might become a suitable dairy animal in the absence of either the yak or of a sufficiently productive cattle population or alternative milk producer. Although these procedures may have little immediate relevance to traditional yak-rearing areas, the idea is intriguing (see also Chapter 16)

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4 THE YAK IN RELATION TO ITS ENVIRONMENT

Overview

Yak have many characteristics and attributes that must be regarded as adaptations to many factors: extreme cold; high altitude with low oxygen content of the air and high solar radiation; difficult, often treacherous terrain; and cyclical nutrition with short growing seasons for grazing herbage as well as a variety of herbage.

In general, temperature is the single most important factor determining the distribution, stocking density and, indirectly, the growth rate of yak. Yak survive and perform adequately if the annual mean temperature is below 5^{o}C and the average in the hottest month is not above 13^{o}C. They can also survive satisfactorily at ambient temperatures down to -40^{o}C. Altitude, as such, is of lesser importance. The further north (of the equator) yak live, the lower, in general, the altitude at which they are found. Yak in North America and in animal and zoological parks in several parts of the world, may again have re-adapted, over time, to life in these, for them, non-normal situations.

Yak cope with cold by conserving heat, rather than by generating it - which would require food that may not be available. Heat conservation is effected by a compact conformation, a thick fleece of coarse outer hair and an undercoat of fine down. The proportion of down in the coat increases greatly before the onset of winter. Young calves have a fleece composed exclusively of down fibre. Normally, yak accumulate a layer of subcutaneous fat prior to winter. This also helps heat conservation and provides an energy reserve. The skin is relatively thick. It contains sweat glands, though for the most part, these are not functional. This is one reason why yak are intolerant of high ambient temperature.

Adaptation to low oxygen content of the air arises from yak having a large chest (14 - 15 pairs of thoracic ribs), large lungs and a large heart relative to their overall body size. The haemoglobin content may not be exceptionally high relative to cattle at sea level, although the content increases with altitude, but the haemoglobin of yak blood has a high affinity for oxygen. Also, anatomically, the yak is designed to be capable of breathing rapidly and take in large amounts of air.

The skin is highly pigmented and the predominant hair colour is black. Both of these attributes help to resist the effects of solar radiation. White yak exist because herdsmen in some localities prefer them.

The large rumen volume of yak relative to body size may be a useful adaptation to foraging herbage under rough grazing conditions. Yak are adapted to grazing a wide variety of plant species: grass, coarse plants and sedges and some shrubs. Yak can graze long grass using their tongues, as is common for cattle, but they can also graze very short herbage, after the manner of sheep, by using their incisor teeth and lips. When ground is covered with snow and ice, they break through the cover to the wilted grass beneath, using their hooves and heads. Yak also graze rapidly and for long hours.

To cope with precipitous terrain, yak have developed particularly suitable hooves and a temperament that is suited to potentially dangerous situations, such as marshy ground. Yak prefer to group in large herds for protection, particularly against wolves, but they are also nervous of wild animals and man and, if startled, will readily take flight.

Introduction

Features common to the environment in which yak live are extreme cold, mountainous terrain, high altitudes with reduced oxygen in the air, high solar radiation and short growing seasons for herbage and a variable assortment of herbage, sparse in some areas. Plant growing seasons vary from 120 to 180 days, but the periods of relatively vigorous plant growth are even shorter than that. Wilted herbage provides some sustenance for the yak at other times of year, but not in sufficient quantity for their requirements. There is, of course, some variation in these features. Some "compensatory" factors have also to be taken into account. For example, the more northerly the latitude at which the yak are found, and hence, in general, the colder the climate, the lower the altitudes at which the yak will live. These points will be discussed in more detail later in this chapter. Many of the characteristics of the yak can be regarded as adaptations to these conditions, in which cattle of other species have difficulty in surviving.

Distribution in relation to environmental factors

Several studies in China have analysed the distribution of the yak using multiple regression approaches with the stocking density of the yak, in selected areas, as the dependant variable and various factors of the environment as the independent variables. The factors most commonly included in these studies (for example, Wen Zhenzhong and Xie Zhonglun, 1985) are: altitude above sea level, yearly average air temperature, annual precipitation, average relative humidity, average annual sunshine and, in some studies, the type of plant cover.

These factors are not independent of each other. For example, altitude and air temperature are related, as are annual precipitation and annual sunshine, and all these factors impinge on the length of the growing season for plants and the type of plant cover likely to be found. With these limitations in mind, authors of various studies concluded that air temperature was of major importance for the distribution and body size of the yak and more important than altitude (Cai Li, 1992; Chen Zhihua, 2000). In analyses where the type of plant cover was also included as a variable (Huang Wenxiu and Wang Sufang, 1980; Dou Yaozong, *et al.* 1985) its importance ranked alongside temperature.

However, the quantity of available herbage itself must be strongly influenced by the climate of the area. Annual precipitation was generally of less importance to the distribution of the yak, and altitude, as such, of lesser importance still.

Some environmental factors in relation to areas of yak distribution are shown in Table 4.1. It can be seen that yak are found generally above 3 000 m above sea level (a.s.l.), with cold and semi-arid to semi-humid climate (yearly average temperature ranging from -5°C to 5.5°C, and average relative humidity from 50 percent to 65 percent). The main natural feeds are grass, sedges and forbs.

The effect of air temperature

In the native regions of yak in present times, the stocking density of yak declines as average annual temperature increases. The greatest concentrations of yak are found at average annual air temperatures between -3°C and +3°C. In Qinghai province, the yak are concentrated in areas with annual mean temperatures between -3°C and -4°C; those in Tibet are densest at the range of -3°C to -5°C; and in Sichuan province between -1.6°C and +3.4°C (Table 4.1).

Table 4.1 Environmental factors in yak distribution areas

Areas	Altitude (m a.s.l.)	Yearly average temp (°C)	Annual precipitation (mm)	Type of plant cover	Sources
Tibet	4 500 - 5 500	-3 - -5	600 - 700	Grass, sedges and forbs	Lu Zhonglin, 1999
Qinghai	4 000 - 4 500	-3 - -4	500 - 600	Grass and sedges	Cai Li, 1994
Southern Gansu	3 000 - 4 500	1.4 - 3.2	300 - 860	Grass and sedges	Lu Zhonglin, 1999
Western Sichuan	3 000 - 5 000	-1 - 5	600 - 800	Grass, sedges and forbs	Cai Li, 1989
Zhong Dian, Yunnan	3 000 - 4 000	5.2 - 5.5	500 - 700	Grass and sedges	He Shaoyu *et al.*, 1997
Bazhou, Xinjiang	2 400 - 4 000	-4.7	Around 284.6	Grass and shrubs	Lu Zhonglin, 1999
Bhutan	3 600 - 4 600	5.5	Below 650	Grass and sedges	Tshering *et al.*, 1996
India	4 000 - 5 000			Grass and forbs	Pal *et al.*, 1996
Mongolia	3 000 - 5 000		350 - 500	Grass and shrubs	Davaa, 1996
Nepal	3 000 - 5 000			Grass and sedges	Sherchand *et al.*, 1996

Li Shihong *et al.* (1981) reported that above an ambient temperature of 13°C the respiration rate of the yak starts to rise, and at 16°C the heart rate and body temperature start to rise. When environmental temperatures reach 20°C, yak will stand near water or in shade, if available, without moving, grazing, drinking or ruminating. At the other extreme, yak can feed and move normally on grasslands with air temperatures ranging as low as -30°C to -40°C, or even lower as in the Tibetan Naqu area where a minimum air temperature in the cold season was recorded as -42°C. The lowest temperature that yak can tolerate has not been recorded.

It appears from these studies that air temperature is the single most important environmental factor influencing the distribution of the yak. Yak survive and perform adequately provided the annual mean temperature is below 5°C and the average in the hottest month does not exceed 13°C, though daily maximum temperatures can rise in the summer to much higher levels before falling again at night. (Nonetheless, yak kept commercially in North America and those in zoological and wild animal parks in many countries appear to have adapted to different sets of conditions - see Chapter 11, part 3). It is a matter of observation that the farther north of the equator that yak live, the lower is, on average, the altitude of the terrain on which they are found because average temperature declines with increasing latitude (cf. Table 4.2).

Air temperature has also been reported as the most important environmental factor influencing the growth and body size of yak (Cai Li, 1992; Yao Yubi and Li Yuqing, 1995; Chen Zhihua *et al.*, 2000). Yao Yubi and Li Yuqing, (1995) derived an equation of meat production from its relation with air temperature by using multiply regression as follows: ? = 2.452 + 7.166T_7 + 1.726 R_2 (r=*0.907,* P<0.01). Where ? is average carcass weight of yak, T is the average temperature of the mid-ten days in July and R is the precipitation in February.

The effect of altitude

Subject to the availability of adequate grazing, the distribution and stocking density of yak increases with altitude, but as already noted, this is also dependent on latitude. Thus, at the more southerly latitudes as, for example, Qinghai province, yak seek out higher altitudes than in more northerly areas, such as Mongolia. The few yak introduced to Canada and Alaska in far northern latitudes existed at relatively low altitudes (see Chapter 11, part 3). It is likely that, as previously suggested, the relationship between altitude and latitude is mediated through air temperature.

The highest altitude where yak live normally is at 5 500 m in the Tibetan Rongbusi region in the lower ranges of the Himalayas. Yak steers used as pack animals are quite capable of traversing terrain at 7 200 m. Low oxygen content of air and high solar radiation are not therefore barriers to the yak's survival.

The effect of precipitation and relative humidity

Yak live in two distinct zones. One is semi-arid with an annual precipitation of 500 - 600 mm and a relative humidity of 50 - 60 percent. In these areas the potential for evaporation tends to exceed the level of precipitation (e.g. Qinghai and much of Tibet). The other zone has an average annual rainfall of 600 - 700 mm and a relative humidity of 60 - 65 percent and is described as semi-humid (e.g. eastern Tibet and southwest Sichuan). The two zones differ in the predominant types of vegetation found and, as noted in Chapter 2, the two zones are associated with different types of yak.

The effect of sunshine

In general, yak live in areas with more than 2 000 hours of annual sunshine. In Qinghai province, the highest densities of yak are in areas with between 2 500 and 2 700 hours sunshine (Wen Zhengzhong and Xie Zhonglun, 1985), while in Sichuan province the greatest density of yak is in the districts with between 2 000 and 2 200 hours of sunshine per year.

Adaptive characteristics

The ability of the yak to live in conditions in which other bovines will not survive, or, at least, not thrive, suggests that the yak has developed specially adapted characteristics. These are described in the following sections.

Resistance to cold

Conformation

The yak's body is compact with short neck, short limbs, no dewlap, small ears and a short tail. (The limb length index, defined as {[height at withers-chest depth]/height at withers} x 100, is small at 40 - 42 percent, relative to other cattle in the region.) The scrotum of the male is small, compact and hairy, and the udder of the female small and also hairy. The skin has few wrinkles, and the surface area of the yak is relatively small per unit of bodyweight (0.016 sq m per kg [Li Shihong *et al.* 1984]). The yak has only a few functional sweat glands (see section, Skin thickness and sweat glands). All these factors result in a minimized dissipation of body heat.

In addition in terms of appearance though not relevant to heat dissipation, yak can be either horned or polled. The distribution of these two forms appears to depend on the regional preferences of the herdsmen. Thus, yak in Mongolia, for example, are predominantly polled (or dehorned) while those of Tibet or Nepal are nearly all horned. The distribution of the horn types is shown in Table 4.2.

Coat of the yak

Heat conservation is enhanced by a thick fleece on the whole body, composed of an outer coat of long hair and an undercoat of a dense layer of fine down fibres that appear in the colder season. As already noted, hair colours vary from black and brown through variegation to white. Since white absorbs less heat, the existence of this colour must be attributed to herders' preference rather than to adaptive usefulness. It is significant, however, that white yak are more prevalent at more northerly latitudes. In such areas, solar radiation is not as intense as in the more southerly latitudes, or at the higher elevations where black is the predominant colour (see Table 4.2). Hair production of white yak is higher than that of the black and brown ones (Wang Yuchang, 1995). The thick and dense coat of white yak may partly compensate for less heat absorption of the white colour in winter.

Details of fleece production and physical and structural properties of the fibres are given in Chapter 6. The purpose here is to discuss the coat as a feature of the adaptation of the yak to its environment.

In general, the coat of the yak seems well suited to insulating the animal from cold, protecting it from heat and repelling moisture. All these factors are important to survival in the prevailing climate. As Yousef (1985) noted, a thick winter coat is a general adaptation of animals living in extreme cold, e.g. arctic mammals. Thus, conservation of heat takes precedence over extra generation of heat. To generate extra heat would ultimately require additional feed, which is in short supply throughout the winter. It is of interest in the present context to observe that one of the most successful of all the yak breeds, the Jiulong yak of Sichuan province, has a fibre strain that produces, on average, between three and five times as much fleece as other types of yak. This strain also inhabits one of the coldest, dampest and most fog-bound areas of all yak territory. It is probable that it is the dense, heavy coat that has helped the Jiulong yak to survive in these conditions.

Insulation from the fleece

The coat consists of three types of fibre: coarse, long fibres with a diameter in excess of 52 m, down fibre with a diameter below 25 m and mid-type hairs with diameters between these two values. The down fibre is a particular attribute of the winter coat of the yak to provide the additional insulation then required. Coats with a mixture of fibre types have been shown to maintain a stable air temperature within the coat. Ouyang Xi and Wang Qianfei. (1984) measured temperatures at the skin surface and at the middle and top of the staples of various parts of the yak body, namely the ear, forehead, sides of neck, shoulder, rump, the back, belly, tail and legs. Measurements were made on ten animals on three successive days in the cold season in February (mean ambient temperature -18°C) and on nine animals on three days in the warm season at the end of May (mean daytime ambient temperature 22°C - though somewhat windier at that time than in February). Figures 4.1 and 4.2 show the measurements.

The results (Figures 4.1 and 4.2) show that the gradient in temperature between the skin surface and the top of the staple is far greater in winter than in summer for parts of the body trunk, such as the shoulder, rump and belly.

Figure 4.1 Temperature °C in summer (mean daytime ambient temperature 22°C) at the skin surface (blue), mid-staple (purple), and top staple (yellow) of various body parts: ***1 back, 2 ear, 3 neck, 4 forehead, 5 tail, 6 shoulder, 7 rump, 8 belly*** **[Source: Ouyang Xi *et al*., 1985]**

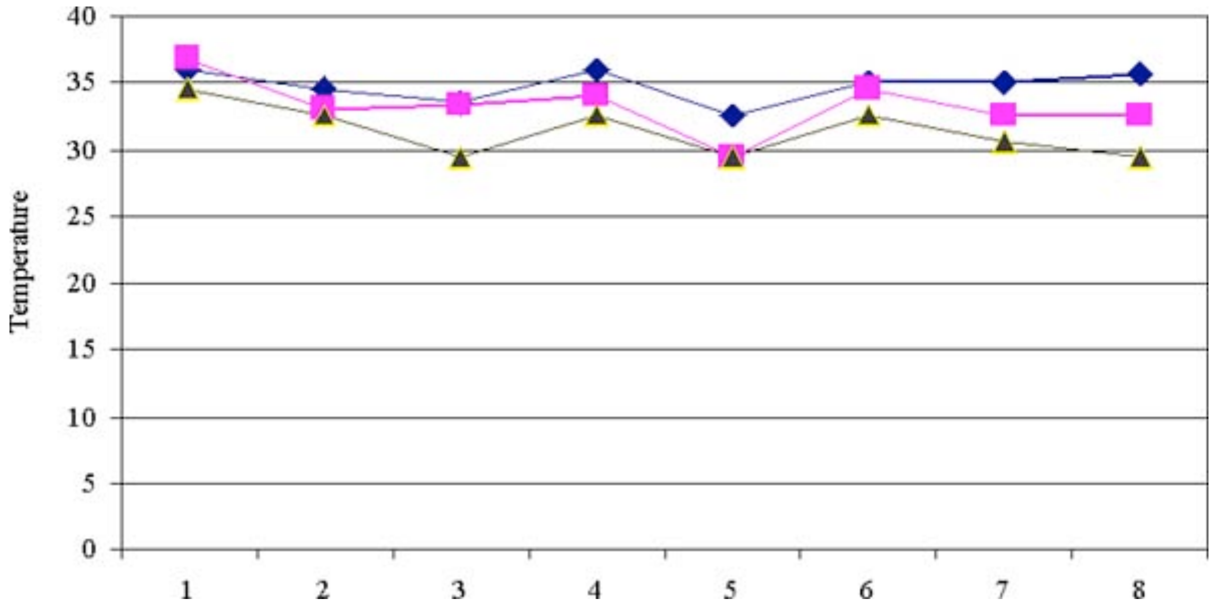
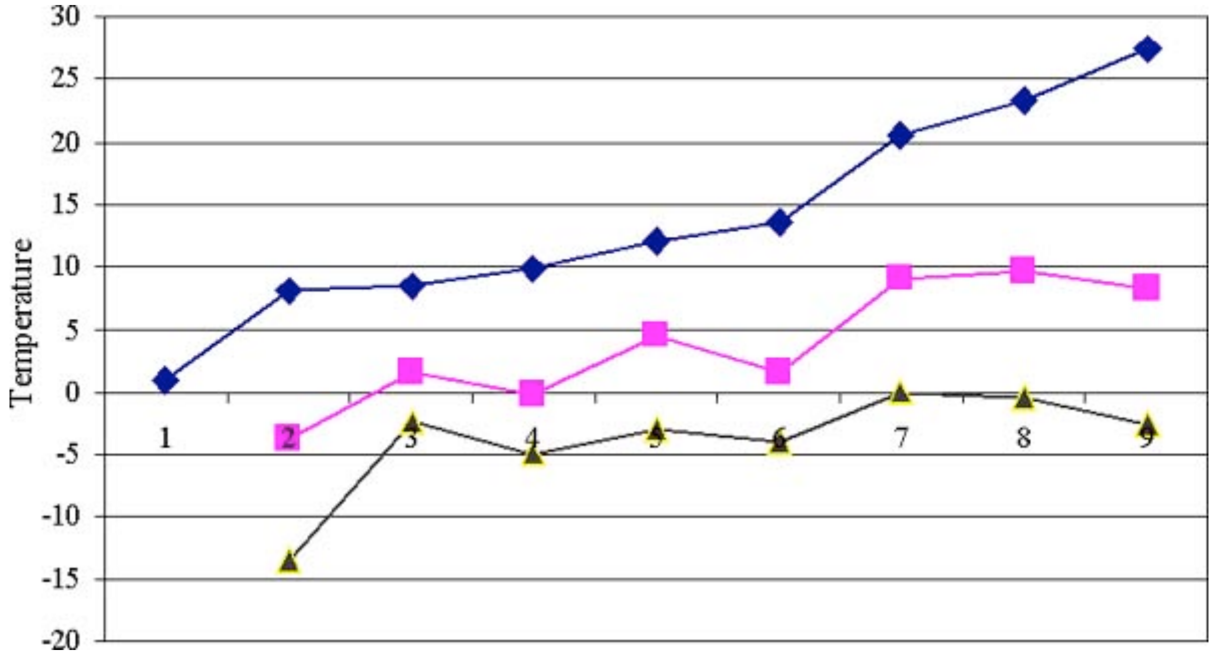


Figure 4.2 Temperature °C in winter (mean ambient temperature -18°C) at skin surface (blue), mid-staple (purple), and top staple (yellow) of various body parts: ***1 leg, 2 back, 3 ear, 4 neck, 5 forehead, 6 tail, 7 shoulder, 8 rump, 9 belly*** **[Source: Ouyang Xi *et al*., 1985]**



However, the seasonal difference in the temperature gradient from skin surface to top of staple is much less at extremities of the body, such as the ears, where vasoconstriction occurs during cold. For this reason, temperature varies at the skin surface, during the cold season, between the different parts of the body, as shown in Figure 4.1. The results also show clearly the insulation from cold provided by the fleece (though these features are not unique to the yak; the effect of fleece on heat regulation, and consequently on the energy metabolism of the animal, have been demonstrated, e.g. in relation to sheep by Blaxter, *et al.* 1959). No case of frostbite has been recorded in the yak, even at the extremities of its body.

The function of the coat in helping yak to survive in very cold and wet conditions is enhanced by the low water absorption of the coat (Xue Jiying and Yu Zhengfeng, 1981).

The *arectores pilorum* muscles are highly developed in the dermis of the yak (Ouyang Xi and Wang Qianfei, 1984). Their contraction makes fibres stand up and effectively increase the depth of the coat and reduce heat loss under stress from cold.

Seasonal changes

Hair growth and the composition of the coat change with season. As air temperature falls with the approach of winter, down fibres grow densely among the coarser hairs, especially on the shoulder, back and rump. Ouyang Xi *et al.* (1983) found in a herd studied both in summer and in winter that the proportion of down fibre increased by between 17.5 percent and 30 percent in winter, through the activation of down follicles that had lain dormant. The proportion of coarse hairs correspondingly decreased. As air temperature rises with the onset of the warm season, down fibres begin to be shed from the fleece (see Chapter 6).

As a consequence of the abundant grazing in summer and early autumn, yak are normally able to develop a layer of subcutaneous fat that also provides them with insulation from cold as well as an energy reserve during the period of nutritional deprivation over winter and spring.

Breed and location differences

The amount of down fibre on the yak's back may vary with breed. From different studies it appears that down fibre is more than twice as dense in Tianzhu White yak in Gansu province as in Luqu yak of southern Gansu, with the Maiwa yak of Sichuan province somewhat intermediate (Zhang Rongchang, 1977; Lu Zhongling *et al.,* 1982; Wang Jie *et al.*, 1984). However, here again, breed type is confounded with the area in which the different breeds are kept. To establish that it is breed and not location that is responsible for the differences would require a comparison of the different breeds at the same location.

Studies also indicate that fibre density declines when yak are moved to areas with warmer summers and longer frost-free periods. Thus, yak introduced in the 1970s to the Jingbei Plateau of northern Weichang county of Hebei province had an average density of fibres of 3 167 per sq cm at that time. The density subsequently declined to 1 870 fibres per sq cm. The changes occurred through a decrease in the density of down fibre in particular, but the coarse hairs decreased in length. These changes allowed better heat dissipation at the warmer times of the year and can be assumed to have occurred in response to the environmental changes directly affecting the animal rather than due to selection among the yak.

Age effects

In calves younger than six months, the coat consists almost entirely of down fibre. Thereafter, the proportion (by weight) declines to 62 percent at one year old and 52 percent by year two, 44 percent at year three and 43 percent at four and five years old (Zhang Yingsong *et al.*, 1982). There is a corresponding increase in the deposition of subcutaneous fat as the animals grew older.

Skin thickness and sweat glands

Xiao Wangji *et al.* (1997) found Zhongdian yak produced more hide and possessed a higher proportion of skin to body weight ($P<0.01$), when compared with Zhongdian cattle and yak-cattle hybrids. Skin thickness is greater on the back of the yak than on other parts of the body. This is associated with the fact that the back is the part of the animal most exposed to wind, rain and snow. Li Shihong *et al.* (1984) measured skin thickness on the shoulder blade, the back and the knee of 70 live female yak and found the average thickness at the three positions to be 5.6 ± 0.36, 7.5 ± 0.83 and 5.6 ± 0.40 mm, respectively. Ouyang Xi *et al.* (1984), using histological sections, measured thickness of epidermis and dermis combined. Again, the back had the thickest skin (average 5.13 mm) and the densely haired parts had a thickness of as little as 2.36 mm. Averaged over the different parts of the body, the skin thickness was 3.37 ± 1.38 mm, but the epidermis itself was very thin at 0.044 ± 0.019 mm.

Sweat glands are distributed in the skin over the whole body and are of the apocrine type. Density per sq cm was found to be greatest on the forehead (891 sq cm) and least on the rump (138 sq cm), with an overall average of 399 ± 251 sq cm (Li Shihong *et al.*, 1984; Ouyang Xi and Wang Qianfei, 1984). However, the function of the sweat glands is poorly developed. Tests made by these authors, using different methods, agree in detecting sweat secretions only on the muzzle and not on other parts of the body. The absence of sweating in the yak assists cold tolerance but helps make the yak intolerant to heat.

Energy metabolism

Hu Linghao (1994) studied the energy metabolism of growing yak at three different ages (one, two and three years old) and compared it with that of yellow cattle, both kept at three different altitudes (2 261 m, 3 250 m and 4 271 m). He reported that the fasting heat production of the yak remained fairly constant irrespective of altitude, whereas that of the yellow cattle rose markedly. This could well point to an adaptive response of the yak to life at high altitude and to the nutritional deprivation that yak experience in winter and early spring.

At the lowest of the three elevations in the trials conducted by Hu Linghao, the absolute fasting heat production of the yak was higher than that of the yellow cattle, but not so at the higher altitudes. In another experiment by Hu Linghao, the yak generated a little more heat in the course of walking than did the somewhat larger yellow cattle. The author attributes the difference in heat production to the difference in body size, as smaller animals are expected to generate more heat. Clearly, these and similar experiments are important for understanding the factors that lead to adaptation and may, in due course, provide a means for devising improved grazing and management strategies.

Adaptation to low atmospheric oxygen and high solar radiation

At elevations of 3 500 m above sea level, where most yak live, the oxygen content of the air is some 35 percent lower than at sea level. On even higher grazing pastures, at an altitude of 5 000 m, the oxygen content is halved. Also, in most of the areas there is more than 2 000 hours of sunshine and levels of solar radiation are between 130 and 165 kcal per sq cm (540 - 690 kJ per sq cm) annually, depending on elevation.

The yak has adapted to these conditions: It is considered to take in larger volumes of air than most other cattle, to retain a higher proportion of the oxygen breathed in and to be protected against harmful effects of solar radiation by the colour of its coat and skin.

Vertebrae, thorax, heart and lungs

Vertebrae. Yak have 14 thoracic vertebrae and 14 pairs of ribs - one more than in other cattle - although several authors report 15 ribs, two more than in other cattle. This gives the yak a larger chest capacity. There are five lumbar vertebrae, one less than in other cattle. The number of coccygeal vertebrae is variable in the range from 12 - 16 (other cattle have 16). The yak has five sacral vertebrae and seven cervical ones, the same as for other cattle. The total number of vertebrae are thus fewer than for other species of cattle.

*Thorax and organs.*Yak ribs are narrow and long with a relatively large distance between them. There is also a good development of muscle between them. Relative to local cattle, the yak has a large thorax (heart girth index = 150 [heart girth x 100/height at withers]), allowing the development of large lungs and a large heart. For example, according to Xiao Wangji *et al.* (1997), the lung of Zhongdian yak (n=12) weighs 3.7 ± 0.54 kg, more (P<0.05 than that of Zhongdian cattle 1.8 ± 0.57 kg (n=5) and yak-cattle hybrids 2.5 ± 0.39 kg (n=10). Similarly, these authors recorded the heart of Zhongdian yak, weighing on average 1.3 ± 0.29 kg, heavier (P<0.01) than the cattle heart (0.87 ± 0.24 kg) or the yak-cattle hybrids heart (0.84 ± 0.11 kg). The larger sizes of these organs help the yak to achieve adequate intake and circulation of oxygen in conditions where the supply is low. Lung weights of the Chinese yak vary among the different breeds, from 1.1 percent to 1.5 percent of body weight, and heart weights vary between 0.5 percent and 0.78 percent of body weight (Li Shihong *et al*., 1984; Zhang Rongchang, 1985).

Denisov (1958) found that the alveolar area occupied 59 percent of the cross-sectional area of the yak lungs, compared with 40 percent for Jargas cattle located nearby. This suggests that the yak lung also has a relatively large surface area from which to absorb air in order to compensate for the lower oxygen content of the air.

The trachea of the yak is also particularly large to allow a high rate of intake of air. Zhang Rongchang *et al.* (1994) stated that the trachea length in Tianzhu White yak is shorter than in other cattle but that the diameter is appreciably greater. Wang Yuchang (1995) confirmed that finding and also referred to large nostrils in the yak that further assist air intake. Li Shihong *et al.* (1984) measured five females and reported 43 cm for the length of the trachea and 5.5 cm for the diameter. Apart from variation in the trachea dimensions among individual animals, the size of the trachea varies with the general body size of the yak, as affected by breed and location. The annular cartilage of the trachea was found to be narrow and adjacent cartilages of the trachea to be about 4 cm apart. This allows the yak to breathe rapidly and to quickly increase air intake into the lungs when conditions demand it.

Circulation and oxygen intake and absorption

Heart and pulmonary pressure. A study of five yak at high altitude (Ladakh, India, 4 500 m) and six yak at low altitude (Whipsnade Park, England, 150 m) by Anand *et al.* (1986) found that the pulmonary arterial pressure was not significantly different in the two groups. But the pulmonary arterial resistance was slightly higher in the yak at high altitude than in those at virtually sea level (0.58 vs. 0.34 mm Hg l^{-1} min). A higher resistance would be expected if vasoconstriction has occurred in the pulmonary arterial system.

Vasoconstriction commonly occurs in order to reduce blood supply to under-ventilated areas of the lung and maintain homeostasis in other respects (Anand *et al.* 1986).

For example, in an animal with a pneumonic lung, the vasoconstriction reflex will shut off oxygen to the damaged area even at low altitude, making more oxygen available to the functional areas of the lung. At high altitude, as Anand *et al.* (1986) argued, such vasoconstriction would not be a good long-term response to permanently hypoxic conditions. Because the whole lung becomes a low-oxygenated area at high altitudes, the vasoconstriction reflex would be very damaging, as it would then affect the whole lung. As shown by these authors from comparisons of yak with cattle, it seems the yak has adapted to prevent this vasoconstriction happening to all but a very small extent.

Thus, when comparing yak with Himalayan (hill) cattle and hybrids of these with yak, all at the high altitude, Anand *et al.* (1986) found that while arterial pulmonary pressure in the cattle was somewhat higher than in the yak, the pulmonary arterial resistance was more than three-fold greater. In these respects, the first-generation hybrids of the yak with these cattle were intermediate in their pulmonary haemodynamics, but considerably closer to the yak. Backcrosses to cattle (three quarter cattle, one quarter yak), however, had a bi-modal distribution - with some animals closer to cattle and others closer to yak, especially in respect to the resistance trait. Anand *et al.* (1986) concluded from this study that there was an inherited basis to pulmonary arterial resistance and that the yak had gone a long way towards eliminating the vasoconstrictor response to high-altitude-low-oxygen living.

Anand *et al.* (1986) provided a cautionary comment to their conclusions by saying that they cannot be certain to what extent the differences in resistance between the hill cattle and the yak are an expression of the differences in the size of the animals (the cattle were much smaller). If the results are confirmed, a genetically attenuated vasoconstrictor response to low-oxygen conditions is clearly an adaptation of importance.

In an effort to explore the subject further, Anand *et al.* (1988) did another study in which sheep and goats were also included. Their later results supported the earlier thesis, in relation to the reduced vasoconstriction response in the yak, and also added data (albeit from only one yak), suggesting that the yak has a relatively larger right ventricle of the heart than what is found in hybrids of yak with cattle. Moreover, the yak, unlike the cattle, had a smaller medial thickness of the small pulmonary arteries (further suggesting a reduced capacity for vasoconstriction).

Belkin *et al.* (1985) reported, on the basis of a study of 40 hearts from mature yak, that there was a higher degree of capillarization of the right ventricle of the heart compared with the left. This suggests a further adaptive response of the yak to high altitude conditions that require the right ventricle to cope with increased loading.

Respiration. Cai Li *et al.* (1975) observed 48 adult female yak at pasture at an altitude of 3 450 m in July and August. Respiration rate was between 20 and 30 per minute when the air temperature was below 13^{o}C, but above that temperature the respiration rate rose rapidly. Respiration rate was significantly higher in the evening than in the morning, but was not significantly correlated with humidity, wind speed or the prevailing weather. Zhang Rongchang (1989) reported a respiration rate in adult yak of 80 per minute at 28°C, 49 per minute at 10°C and 25 per minute at 5°C. For one-year-old yak, the respiration rate at the high temperature was as high as 130 per minute but declined to 7 - 15 breaths per minute at -6°C. A study by Wang Yuchang (1995) on Tianzhu White yak found both respiration rates and pulse rates to be higher in the females than in males.

As expected, respiration rate was also found to be higher during periods of activity than during inactivity.

Zhao Bingyao (1982) examined seasonal differences in the respiration rate in five adult female yak at an altitude of 3 400 m on cold grassland. Over a period of a year, the animals were observed each day between 0600 hrs and 0800 hrs and again between 1800 hrs and 2000 hrs. The respiration rate was found to be highest in August and pulse rate highest in June. Both rates declined gradually after the warm season ended and were at their lowest in March. Body temperature was virtually unaffected by season and averaged 37.6°C in the morning and 38.5°C in the evening. All of this suggests that yak alter their respiration rate not only in response to a changing need for oxygen, but also to regulate body temperature. The yak, with its thick skin, absence of sweating and a heavy coat, has few means at its disposal for heat dissipation, other than respiration rate. The lowest pulse rate in March corresponds to the time of year when yak are in their poorest condition and often at a point of exhaustion. At this time, they have a low metabolic rate due to the prolonged period of a shortage of feed over winter that leads to near starvation.

Blood cells and haemoglobin. The capacity to take in sufficient air by virtue of anatomical features, respiration rate and physiological response is clearly an important aspect of yak adaptation to life at high altitudes. It is also important that absorption and retention of oxygen from the air should be adequate for the need. This, too, may be specially adapted in the yak. In this regard, the evidence from red blood cells and haemoglobin (Hb) content is not totally conclusive. Data from 21 different sources are presented in Table 4.3. These results suggest that, relative to adult cattle (*Bos taurus*) at or around sea level, the yak in these various studies do not have exceptionally high numbers of erythrocytes per unit volume of blood. The values range from 5.2 to 10.3, with an average of 6.9 (10^{12} per l) for the 16 mean values shown. This compares with a mean of 7.0, and a range from 5.0 to 9.0, given as normal values for other cattle in a review article by Doxey (1977).

The overall average of the 21 Hb values (g per dl) in Table 4.3 is 11.8 (range of averages from 8.3 to 18.4). These values are only slightly higher than the overall average of 11.0 (8.0 - 14.0) given as the normal values by Doxey - and the mean values of only two of the groups of yak fall outside the range for the cattle examined. The data in Table 4.3 indicate that the haemoglobin concentration in blood increases, in general, with increasing altitude, particularly if only the data from yak at the several highest altitudes are considered. Interestingly, the values for yak at Whipsnade Park, a little above sea level, were similar to the values for yak from China, Bhutan and India. Taking account of the altitude effect, it seems that yak are not exceptional relative to cattle. (There is no particular explanation for the fact that two of the values quoted by Zhang Rongchang *et al.*, 1994, for yak in Tibet at altitudes of 4 366 m and 4 500 m, are markedly higher than the other values from that area. Sampling errors cannot be ruled out because the number of animals involved is not given). Only a few authors provide data on packed cell volume (PCV). These are, on average, higher than the normal mean given in the article by Doxey, previously mentioned. None are outside the range he quotes. A useful parameter, which can be derived from a combination of PCV and red-cell count, is the mean corpuscular volume (MCV), which provides an indication of red-cell size. The average of the seven estimates available is 59.8 and puts this at the top of the range quoted by Doxey for cattle. This, then, may indicate that yak have larger red cells with a greater surface area and a higher capacity for the retention of oxygen. (Larrick and Burck, 1986, in a general article on yak in Tibet, give a contradictory view by suggesting that yak have very small red cells in relation to sea-level bovines but have vastly more cells per unit volume of blood; unfortunately no actual data or references are provided to verify this claim.)

An intriguing paper by Lalthantluanga, *et al.* (1985) showed that two types of a and two types of b chains are found in the yak haemoglobin, and that there has been a substitution of valine at position 135 of the b^{II}-chain, in place of the more usual alanine. This was considered by the authors to be the reason for the intrinsically higher oxygen affinity of yak haemoglobin, compared to that of lowland cattle, which is quoted by them and other authors as an established finding in the yak.

It seems, therefore, that factors concerned with air intake, combined with a high oxygen affinity of yak haemoglobin, provide the basis for the yak's adaptation to life at high altitudes.

One final note regarding Table 4.3: Attention is drawn to the difference in blood values at Whipsnade Park between yak manually restrained and those sedated with xylazine. The act of struggling by the animals in the course of manual restraint was shown by Hawkey *et al.* (1983) to release reserves of red cells from the spleen and hence raise the values of several of the blood parameters above those of sedated animals. This point was noted by Winter *et al.* (1989) who also sedated their animals. It has to be assumed, in the absence of information to the contrary, that all the other estimates presented in Table 4.3 are based on manually restrained animals. Therefore, the values from the majority of the sources are likely to be higher than they would have been from sedated animals. It seems possible that the degree of struggling by the animal in the course of restraint may also affect the results, though there are no data presented on that point.

Seasonal variation in Hb content. There is some seasonal variation in the Hb content of yak blood. It is relatively low in May (10.5 g per dl) and higher in October, after the end of the summer grazing season (14.6 g per dl, based on some observations of female yak in Menyuan county of Qinghai province (Research Co-operative Group, 1980 - 1987).

Similar observations were made on yak in parts of Siberia by Belyyar (1980), who recorded an Hb content of 10.2 g per dl in the spring and 12.8 g per dl in the autumn of the same year. He also noted that the diameter of the erythrocytes in these yak was 4.83 m, which was larger than for contemporary Yakut cattle (4.38 m) in the same area.

Cai Li *et al.* (1975) also provided some evidence on age differences and the difference between lactating and dry adult females. Age effects were not significant on the numbers involved (groups of 17 to 58 for female yak). However, lactating yak had lower red cell counts than dry cows (as shown in Table 4.3 for data from Ruoergai).

Table 4.2 External characteristics of yak at different locations varying in altitude

Area	Location*			No. observed	Polled (%)	Black/ brown (%)	Black with white patches (%)	Variegated (%)	White (%)
	Latitude (N)	Longitude (E)	Altitude (m)						
Tibet, Pali	27.5	89.0	4 300	529	few	89.0	11.0		
Yunnan, Zhongdian	28.0	99.5	3 300	946	0.0	62.4	37.6		
Sichuan, Muli	28.5	101.0	3 500	772	0.0	9.5	90.5		
Sichuan, Jiulong	29.0	101.5	3 800	337	0.0	75.4	24.6		
Sichuan, Liuba	29.5	101.5	3 800	4455	0.5	50.6	49.2	0.1	
Tibet, Pengbuo	30.0	91.5	4 000	96	Few	75.0	15.6	9.4	
Tibet, Dangxiong	30.5	91.0	4 400	591	0.0	91.9	8.1		
Tibet, Jiali	31.0	93.5	4 500	241	17.0	41.0	50.0	9.0	
Sichuan, Shachong	31.0	101.0	3 200	486	1.6	78.1	21.9		
Sichuan, Ganzi	31.5	100.0	3 800	330	3.0	66.0	31.0	3.0	
Tibet, Naqu	31.5	91.7	4 570	795	9.2	78.4	16.1	5.1	0.4
Sichuan, Seda	32.5	100.5	3 893	245	11.8	75.1	21.6	2.5	0.8
Sichuan, Hongyuan	33.0	103.0	3 500	782′	7.4	69.4	22.1	8.1	0.4

Gansu, Gannan	34.0	103.0	3 400	957	57.1	78.2	15.8	6.0	0.1
Qinghai, Tongde	35.0	100.5	3 300	580		81.7	14.1	4.1	
Qinghai, Haiyan	37.0	101.0	3 500	1065	80.0	60.7	25.7	12.7	0.9
Qinghai, Menyuan	37.5	101.5	3 300	1383	43.6	58.2	23.1	7.8	10.9
Qinghai, Gongda	37.5	100.0	3 500	2576	60.6	73.7	16.1	8.1	2.1
Gansu, Shandan	38.5	101.5	3 000	463** 109	46.2	71.6	22.0	5.5	0.9
Xinjiang, Bazhou	40.0	84.0	2 500	280	22.7	57.9	17.5	19.3	5.3

* Median latitude and longitude for the area in question
** 463 observed for horned/polled, 109 for hair colour

Table 4.3 Red cell counts, haemoglobin (Hb) concentration, packed cell volume (PCV), and estimated mean corpuscular volume (MCV) in adult yak from various sources

Area	**Altitude (m)**	**No.**	**Red cell count [10^{12}/l]**		**Hb count [g/dl]**		**PCV [l/l]**		**MCV [fl]**	**Note**	**Source**
			Mean	**[SD]**	**Mean**	**[SD]**	**Mean**	**[SD]**			
UK, Whipsnade Park	150	7	6.4	0.39	13.7	1.7	0.38	0.04	59.3	(m)	Hawkey *et al.*, 1983
UK, Whipsnade Park	150	18	5.4	0.7	10.9	0.9	0.31	0.04	57.4	(s)	Hawkey *et al.*, 1983
USSR, Yakutia	650	26	5.8	0.1	11.5	0.34	0.38	0.014	65.0		Zhang Rongchang *et al.*, 1989 [quote]
Mongolia	1 500				10.0	1.0					Katzina, 1997 [quote]
Xinjiang, Bazhou	2 500	5	7.3		8.3						CCOYSR, 1982
India,	2 750	6	5.2	0.2	10.7	0.4	0.28	0.012	53.5		Mondal *et*

Dirang											*al.,* 1997
Gansu, Tianzhu	3 000	35	6.6	0.9	8.6	1.2	0.33	0.03	50.4		Zhang Dasou *et al.*, 1985
Tibet, Linzhi	3 000	??			11.3						Zhang Rongchang, 1994 [quote]
Yunnan, Zhongdian	3 300	11	6.6		10.0						CCOYSR, 1982)
India, Sikkim	3 300	10	6.1	0.4	13.2	0.2	0.39	0.05	58.0		Sahu *et al.*, 1981
Qinghai, Gonda	3 400	57	6.9		10.3						Li Jinxuan, 1984
Sichuan, Ruoergai	3 450	56	10.3	1.1	12.9	0.9				dry	Cai Li *et al.*, 1975
Sichuan, Ruoergai	3 450	52	7.5	0.9	12.7	0.7				lact	Cai Li *et al.*, 1975
Sichuan, Hongyuan	3 500	5	7.6		10.7						Liu Qibui, 1983
Bhutan, (east)	4 000	13			13.5	1.3	0.39	0.04		(s)	Winter *et al.*, 1989
Qinghai, Huzhu	2700 - 4100	43	6.0	0.93	10.3 (40)*	2.2	0.32 (70)**	0.06			Ma Sen, 1997
Qinghai, Darri	4200	38	6.9		10.8						Xu Rongchan & Wu Zhiqiang, 1984
Tibet, Naqu	4366	??			15.4						Zhang Rongchang *et al.*, 1994 [quote]
Tibet, Dangxiong	4400	30	7.4		11.6						Tang Zenyu *et al*. 1982
Tibet, Longzhi	4500	??			18.4						Zhang Rongchang *et al.*, 1994 [quote]
Tibet,	4700	10	7.6		13.6						Huang

Yagao											Wenxiu & Wang Sufang, 1980

* Number of yak is 40.
** Number of yak is 70. (S) = Sedated with xylazine; (m) = manually restrained; others: form of restraint not specified, manual restraint assumed; dry = dry adult females; lact = lactating adult females.

Other blood cells and constituents

Most of the papers quoted in Table 4.3 also provide values for white-cell content of the blood. They average 10.2 (10^6 per litre) (8.6 - 12.5), suggesting that the animals were in normal health at the time of bleeding. White cell content of the blood of Tianzhu White yak is about 9.1 - 12.5 (10^6 per litre), higher than that of local cattle, 7.6 (10^6 per litre), according to Zhang Rongchang's report (1989)

Cai Li *et al.* (1975) showed (Table 4.2) that, as expected, lactating females had significantly lower blood glucose levels than dry females (61.5 vs. 66.5 mg per dl). Blood calcium and phosphorus concentrations (mg per dl) for the different groups of females in this study ranged from 8.7 for dry adult cows to 9.5 for calves (for Ca) and from 5.5 for the dry cows to 7.4 for the calves (for P). The blood pH was 7.0, on average, in these data.

Colour of coat and skin

The predominantly dark coat colours of the yak (see Chapter 2) help to protect it against the effects of solar radiation, which is particularly intense at the southern latitudes. The lighter colours and white yak are found farther north and at lower altitudes where solar radiation is less intense. However, were it not for selection and colour preferences by man, it is unlikely that the lighter shades, and white yak in particular, would exist. These light shades are not generally found among wild yak where these would be expected to be at a disadvantage in terms of natural selection. Hair colours of yak, in different areas at different elevations, are shown in Table 4.2.

The cells of the epidermis of the yak contain many pigmented granules, especially in the cells of the *stratum basale*. These pigmented granules can help to prevent injury from ultraviolet light in the deeper layers of the skin. Yak with white faces generally have eyes surrounded by black hair. The black eye sockets of Maiwa yak of Sichuan province are accepted as a breed characteristic. Also, the hair on the yak's forehead is well developed and can cover the eyes. No specific research appears to have been done on the possible protection against solar radiation afforded to the eyes and face by this forehead hair, but it is reasonable to assume that the hair has such a function.

Adaptive characteristics related to grazing conditions

The cold pastures on which yak graze have predominantly short grass in some areas and rough grazing conditions with sedges and shrubby plants in others. Yak have developed organs for food intake and a grazing behaviour peculiarly suited to this environment.

Grazing procedure and grazing behaviour

Mouth. Yak have broad mouths, small muzzles and thin flexible lips. The front (incisor) teeth are hard and broad and have a flat grinding surface. The tip of the tongue is also broad and blunt and the filamentous papillae on the surface of the tongue are highly developed and cutinized. The surface of the tongue feels rough and "thorny".

Grazing habit. Yak can graze long grass, using their tongue as do other cattle, but they can also graze in the manner of sheep, using incisor teeth and lips to graze short grass and creeping stems, and roots of grass. Yak will also take tender branches of shrubs in alpine bush meadow. Under most normal conditions, yak have learned to avoid poisonous or thorny plants as recorded instances of poisoning are very rare. However, there are reports of extensive pyrrolizidine alkaloid poisoning in Merak Sakten, a part of Bhutan (Winter *et al.*, 1992). This was thought to be due principally to grazing of *Senecio raphanifolius* (although other plants may also have been involved) (Winter *et al*., 1994). This plant, as pointed out by the authors, was almost certainly eaten by the yak because of overstocking of the pastures concerned, leading to overgrazing. Otherwise, with a more plentiful supply of feed, the yak would have avoided these plants.

Yak will also readily graze the rough stems and leaves of sedges in low-lying marshy areas. Zhou Shourong (1984) recorded more than 60 species of grasses in the diet of yak on alpine, subalpine marsh and semi-marsh meadow (see also Chapter 13). When the ground is covered with snow, as it typically is for long periods, yak will paw through quite thick snow layers, using both head and face to help them to gain access to the wilted vegetation underneath.

Yak will reduce grass with a height of 15 cm to between 2.6 cm and 5.2 cm (Ren Jizhou and Jing Juhe, 1956). In the spring, yak will graze green shoots no more than 2-3 cm above the ground - though it would be surprising if they could not graze more closely than that if necessary (as sheep in Scotland, for example, are known to do). In addition, the yak take stems and leaves from the residual wilted grass still available in the spring.

The grazing time of yak is affected by season, weather, type and quality of grazing and the structure of the herd in terms of age and sex. This has been studied by many researchers (e.g. Ren Jizhou and Jin Juhe, 1956; Cai Li, *et al*. 1960; Zhang Rongchang *et al*., 1982; Qi Guangyong, 1984; Lei Huanzhang *et al*., 1985; and Zhang Hongwu, *et al.,* 1985).

The general conclusions are that the intake time varies between 34 percent and 80 percent of the total time available for grazing. The rest of the time is used for walking, resting and drinking. Normally, lactating yak herds spend more time grazing than do mixed herds - as also found in other grazing cattle. However, in herds of mixed age, where females have young calves at foot, the grazing rhythm is disturbed as the calves suckle and also learn to graze. Under such conditions, the intake time may be curtailed.

The speed with which the yak moves over the pasture varies with season and pasture conditions, but it is usually faster at the start of the day than later on, and it is also more rapid in the cold season than in warm weather. With the approach of snow or hail storms, yak can be seen to run over the pasture, in bursts of speed up to 57 m per minute - up to four times the normal speed at the start of the day.

There is relatively little variation in the bite rate - around 0.8 - 1.1 mouthfuls per second, but intake varies with season, sward height and other factors. Intake ranges from around 28 kg to 38 kg herbage over a period of ten hours in the summer to only 13 kg or less in the same period when grazing wilted grass in the cold season. The energy and protein intakes are adequate to meet maintenance, work and production, but in the later parts of the winter and the early spring they fall below the requirements. Yak then lose weight and condition.

Rumen volume

Xiao Wangji *et al*. (1997) reported that the rumen volume of Zhongdian yak relative to their body size was larger than in the local cattle ($P<0.01$). And the report from Zhang Rongchang (1989), see Table 4.4, showed that the rumen of yak was better developed than that of the cattle, based on the proportion of the weight of different parts to the total stomach. A large rumen may be a useful adaptation to forage roughage achieved by natural selection under the particularly rough grazing conditions prevailing in the yak territories.

Table 4.4 Proportion of each part as a percentage of the total stomach of yak and cattle [Source: adapted from Zhang Rongchang, 1989) (n=6, ±SD]

Stomach part	Tianzhu white yak	Kirgizia yak	Kirghiz cattle
Rumen	72.2 ± 4.2	64.0	51.9
Reticulum	5.6 ± 1.0	7.5	13.1
Omasum	10.4 ± 1.3	17.5	27.2
Abomasum	11.8 ± 1.7	11.0	7.8

Rumination

Under normal conditions, when grass is abundant in summer, yak have four periods of rumination each day. The first of these is generally two hours after the start of morning grazing. A second period is around noon, when the ambient temperature is high and yak stop grazing. A third period of rumination occurs about two hours before the animals are driven from the pasture back to the campsite. A fourth period is in the evening. Rumination periods generally last between 0.8 and 1.9 hours.

If yak are allowed to graze at night, as well as during the day, the periods of rumination are different. In yak used for work, the periods of rumination fit in with the timing and intensity of the work being performed. Occasionally yak will ruminate at night, but usually they lie in a state of light sleep.

Contractions of the rumen reticulum was studied in 48 yak over a three-day period (in Rouergai county, Sichuan) and showed contractions at the rate of 8.7 ± 1.6 (mean and SD) per five minutes immediately before grazing, and almost the same (9.0 ± 1.2) after grazing. Similar results were obtained at other locations.

In other types of cattle, the frequency of contractions when the animal is resting or ruminating may be only half the rate during feeding (Phillipson, 1970). It is possible therefore that the results on yak suggest a different behaviour, which could reflect an adaptation to the grazing conditions.

Sure-footedness

Yak can walk freely in precipitous places at high altitudes, which cannot be reached by horse or sheep (very few domestic goats are found in these areas) and they can cope well with marshy ground. As described by Phillips *et al*. (1946), yak, if in danger of sinking in a marsh, will spread out their legs and use the underside of their bodies to prevent themselves from sinking. They will plod on with a swimming-kind of motion rather than panic and thrash around as a horse might. Yak can swim across rapids and are at ease trekking through snow. They can even be used to make tracks through the snow to clear paths for people - a sort of "biological snow plough".

To help in meeting the challenges of difficult terrain and inclement climate, yak have strong limbs and small hooves of compact texture, with a narrow and sharp hoof tip, hard hoof edges and a close hoof fork. There is an area of soft cutis on the sole.

As noted by Zhang Rongchang (1985), the characteristics of the yak hoof make deep imprints in the ground that allow the yak to control its momentum when going downhill - an important component of its aptitude to move freely in difficult, precipitous terrain.

Adaptation of reproduction

Zhang Rongchang *et al.* (1994) argued that two aspects of yak reproductive characteristics (see Chapter 5) are also adaptive responses to the environment. First, the higher the altitude where the yak live, the more delayed is the breeding season. (For example, according to these authors, it begins 29 May at 1 400 m a.s.l., 10 - 15 June at 2 100 - 2 400 m a.s.l., 19 - 22 June at 2 700 m a.s.l., 25 June at 3 000 - 3 800 m a.s.l. and the beginning of July at 4 570 m a.s.l.). This allows calves to be born in somewhat warmer weather or closer to the onset of such weather and during, rather than before, the start of significant grass growth in the following warm season. From that point of view, a delay in the ability to breed must be regarded as a sensible adaptive response. Nonetheless, one must question whether nature, in this case, has not chosen a second-best strategy because yak that are mated late in the season have less chance of being re-mated that year, should conception have failed, than females mated earlier in the season. Also, calves that are born late in the year have insufficient time to get into good body condition to improve their chances of surviving the rigours of their first winter.

A second adaptive response claimed by these authors is the short gestation length of yak females (258 days on average; see Chapter 5) relative to other species of cattle. Short gestation, with consequently smaller calves, leads to a less stressful and quicker parturition, a lower oxygen requirement by the calf and less body-weight loss by the cow. These factors must be of some importance in the yak environment, especially in the face of danger from wolves. However, it could be debated that the consequent, relatively low birth weight of the calf may be a disadvantage to the calf.

Another aspect of reproduction in the yak that might be regarded as an adaptation to its environment is that many yak females show only one oestrus in a breeding season and, if not then pregnant, the next occurrence of oestrus will be delayed to the following year (see Chapter 5). It is thought, though hard evidence is not presented, that priority is given by the yak to the deposition of internal fat reserves late in the breeding season rather than to conception. This helps the animal survive the ensuing harsh winter and spring when feed becomes in such short supply as to leave the yak starving. (Under more favourable feeding conditions and in some countries, however, as discussed in Chapter 5, yak regularly come into oestrus several times in one season).

General behaviour in relation to adaptation

Behaviourally, the yak is active and easily excited and can have a ferocious temper. Its conditioned reflexes make it respond rapidly to danger and external forces. In the grazing situation, yak will often jump and run, pursuing each other with tail in the air. Yak can gallop like a horse - an attribute that is enjoyed by herdsmen who organize annual races. Yak can also roll over on pastures as horses do - but unlike other bovines.

Yak have the ability to be readily trained. This ability helps the herdsmen in the feeding and management of the yak, especially as most yak graze year round and are not housed and not usually fenced in or tethered, except for milking. In some pastoral/agricultural areas of Mongolia, housing is sometimes practised (see Chapter 11, part 2). The yak are trained by the herdsmen to return to the campsite by the call of their names, or by special cries or singing. Yak are also readily tamed and trained for use as pack animals or for riding. Once trained, yak retain their acquired behaviour.

Yak are easily frightened and vigilant to attack by wild animals, wolves in particular. The yak will form a defensive position and fight off aggressors. It is often reported, for example from the grasslands of western Sichuan province, that male yak have killed wolves with their horns.

Yak are very gregarious. In herds of 100 or more, it is highly unusual to lose an animal from attack by wild animals, as the yak protect each other. When grazing, they are never far apart from each other. Yak can get very frightened if attacked suddenly while resting and not on guard. In such a case, they will flee from the herd and may then be killed by wild predators. Also, when startled on a hillside from above, by either human disturbance or by cries from wild beasts, they can panic and slip or roll down a hill and die in the fall. Dong Baosen (1985) reported that 312 yak died after rolling downhill in four separate instances in Gen county of Xinjiang - three of these due to incorrect driving of the yak by the people involved.

In ones or twos, yak are difficult to drive or manage, although some yak steers trained as pack animals will work individually, as will yak trained for ploughing. Yak will even find their way back to the campsite without a herder - if it is not too far away. Groups of ten or more yak steers trained as pack animals, however, can be easily managed as a group.

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5 REPRODUCTION IN THE YAK

Overview

In general, the reproductive rate of the yak is low under the normal grazing and rearing conditions of the principal yak territories. Female calves born early in the year may show oestrous for the first time when 16 - 18 months old. But those born later in the season will not show oestrous until they are more than two years old. Yak are seasonal breeders with mating and conception restricted to the warm part of the year. In a few areas, under favourable conditions some of the yak may be mated for the first time after they have reached the age of two years or, very exceptionally, even a year earlier. Normally and in most places, yak are not mated for the first time until they are three years old, and often not until four years. Thereafter, female yak are most likely to calve once every two years or twice in three years - producing, on average, perhaps four to five calves in a lifetime. Many yak cows will have only one annual oestrous, irrespective of whether they calved in that year or not. The next oestrous will often not occur until the following year. Under better conditions, in some areas and some countries, yak cows do show oestrous up to three or four times in a season, if they are not already pregnant. Statistics for Hongyuan county of Sichuan province, over the period 1976 - 1980, showed that from nearly half a million female yak of breeding age, 43.8 percent produced calves, which also survived, in any one year. Some breeds, such as Jiulong yak, may do better, and so will yak in areas where improved husbandry is practised. Clearly, the seasonal and general environmental conditions affect the reproductive rate markedly. In exceptionally harsh years, mortality rates of cows and calves can be very high.

Behavioural changes in the yak cow resulting from oestrous are not usually as clear as in other domestic cattle. The duration of oestrous is normally less than a day, although some reports give longer averages, and the range for individual animals is much greater. The average length of the oestrous cycle is approximately 20 days. Gestation length on average is around 258 days, shorter than in other cattle. It is longer when male calves are carried by the dam than it is with female calves. Also, the gestation length is longer, by as much as 20 days on average, when the yak female carries an F1 hybrid calf (having been mated to a bull, or inseminated with semen, of another species of cattle). Abortions and other causes of premature termination of pregnancy are between 5 percent and 10 percent when yak are bred pure, but higher in interspecies hybridization when the calves born are much heavier.

Physiological parameters in oestrous and gestation are similar to those in other types of domestic cattle. Hormonal treatment can be used to induce oestrous and can increase reproductive rate, though the evidence on conception rates following such induction is somewhat conflicting. Conception rates are nearly always much better following natural mating than after artificial insemination.

There is sufficient evidence to suggest that the reproductive rate of yak can be increased by a variety of improvements in management and feeding and by techniques to increase oestrous frequency and the conception rate. Successful detection of first oestrous and good timing of mating can be useful aids particularly when mating is artificially controlled or assisted. Whether the economic rewards from such improvements are a sufficient incentive to incur the costs involved is a separate question.

Male yak start to show mounting behaviour around the age of six months, but sperm have not been found in the ejaculates of yak males before the age of two years. Bulls usually start to mate at three or four years old but then have to establish their position in the mating hierarchy of the herd. Bulls reach the peak of their mating ability around the age of six to seven years. Bulls fight with each other for possession of females, and the dominant bulls have the most mates.

When left to their own devices, yak cows will not allow a bull of another cattle species to approach them, and such a bull has no chance of mating when in competition with a yak bull. In the same way, yak bulls prefer females of their own species. Wild yak bulls, however, will readily mate with domestic yak. All matings of yak cows with *Bos taurus* or *Bos indicus* bulls have to be assisted by people, either through keeping yak bulls away from the females or, more often, through restraint of the cow followed by use of a bull or artificial insemination.

Introduction

The survival and spread of the yak species over the centuries testify to an adequate level of reproduction for this purpose - in the face of an adverse environment. In the context of livestock improvement, however, it is important to consider the limits set by reproductive rate. The reproductive rate affects the opportunities for selection of improved pure-bred stock and also the opportunities for hybridization systems where the yak cow is the dam, which normally depend on "surplus" numbers of pure-bred yak available to sustain hybridization. The reproductive rate also affects the economics of yak production. The purpose of this chapter is, therefore, to document the reproductive performance of the yak under various sets of circumstances. Consideration will also be given to components of the reproductive process, in order to indicate which of these is the most limiting, or most amenable to change in the yak.

The information is derived from investigations on experimental stations or in herds to which the investigators have been given access. Because farms or herds involved in investigations are, in that sense, exceptional, it cannot be known with certainty whether the results obtained are fully representative of those applicable to ordinary herds in remote areas. This problem is not unique to yak but needs to be considered in assessing the results. In situations where the taking of observations and records is not usual, the act of doing so might have led to some improvement in performance.

Some results are also provided on anatomical features and physiological parameters of the yak in relation to reproduction. Male reproduction will be considered in a separate section from the reproduction of females.

Reproduction in the female

Female organs

The structure of the reproductive organs of the yak differs in some respects from those of dairy cattle of the *Bos taurus* type. In order to facilitate and improve techniques for artificial insemination, Cai Li (1980a) dissected the reproductive tracts of 38 female Jiulong yak over the years 1976 - 1980 and found that:

- The cervix has three transverse circles (a very small number of yak have four).
- Each circle consists of many small, tight folds (19 on the outer circle, 13 - 15 on the middle circle and nine to ten on the inner circle).
- The cervix is less than 30 cm from the vulva.
- The cervix is 5.0 ± 0.9 cm long and 3.2 ± 0.7 cm in diameter.
- The *corpus uteri* is relatively short, with a length of 2.1 ± 0.8 cm.
- A long and distinct septum (approximate 6 cm long) extends downward from the bifurcation of the uterine horns towards the *corpus uteri* (and is part of the wall separating the horns).

Cui and Yu (1999) published a study detailing a number of the anatomical features of the reproductive tract of female yak at age one month, one year, two years and seven to ten years old (using a total of 45 animals). Included in their study are the size and weight of the ovaries (on average only a little more than 2 g in weight in the oldest group of 14 cows), the numbers of follicles exposed (on average between three and seven on each ovary but for some reason significantly lower in the two-year old females), and various dimensions of the uterus and uterine horns, oviducts and cervix. The cervix length and diameter (width) recorded by these authors was less than noted previously from the results of Cai Li - possibly because it involved a different type of yak (the Gannan yak) from a different location.

When using artificial insemination, the short *corpus* and the long septum make it reasonably easy to deposit semen in optimal positions, such as the *corpus uteri*, uterine horn or its tip, especially as the cervix is relatively free within the pelvic cavity and can be readily held.

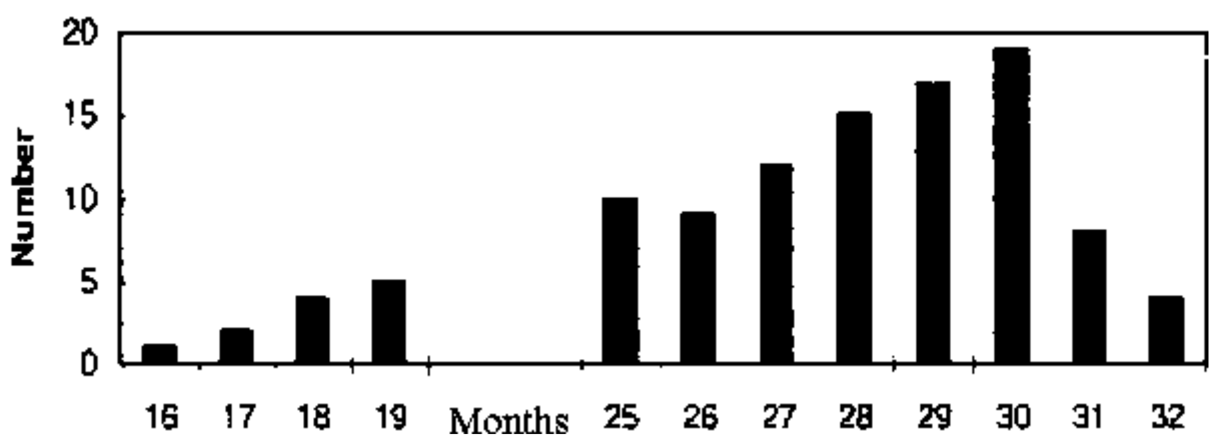
Nonetheless, deep insemination of female yak, using a recto-vaginal technique, is more difficult in the yak than in ordinary dairy cows. The histological structure of the reproductive organs of the yak is similar to that in dairy cattle (Qiu Zhongquan and Zhu Qimin, 1981).

Oestrous of the female yak

Puberty

Generally, first oestrous occurs in the second or third warm season (summer and autumn) following birth, at ages between 13 and 30 months. Generally, puberty occurs earlier in yak with larger body size under better nutritional conditions (Zhang Rongchang, 1989). Magash (1991a) made a detailed study of 104 female yak in Mongolia. The distribution of first oestrous in his study is shown in Figure 5.1. As noted already, oestrous occurred only in the warm season.

Figure 5.1 Frequency distribution of first oestrous in 104 female yak in Mongolia, by age [Source: Magash, 1991a]



The results of Magash (1991a) show that little more than 10 percent of the female yak came into oestrous for the first time in the second summer of their life, and that most females did not show oestrous for the first time until their third summer, when they were more than two years old. Magash pointed out that the 12 females that showed first oestrous when they were 16 - 19 months old had all been born in March or April of the previous year - and had managed to make more growth before the onset of winter than those born later in the season. Those not born until May or June had first oestrous delayed for a year, when they were 25 months old, or older. Magash concluded that the onset of first oestrous was determined more by body development at the beginning of the breeding season than by age. Very similar results, based on observations on yak in the (then) Tuva autonomous republic, were reported by Katzina and Maturova (1989). Yu and Li (2001) found, in 60 yak heifers in Gansu, that the sexual maturity in terms of cyclic activity came when the animals were 33 ± 6.7 months old.

In China, the majority of yak are mated for the first time at the age of three years - in the fourth warm season following birth, but under favourable conditions some yak may be mated a year earlier. Such conditions prevailed among 197 primaparous Jiulong yak cows in Sichuan province studied by Cai Li *et al*. (GAAHB and YRO, 1980): 32.5 percent of them calved first at three years old, 59.9 percent at four years, 6.1 percent at five years and the remaining 1.5 percent (three yak) at six years old. As shown in the next chapter, the three-year-old Juilong yak had reached about 78 percent their mature body weight (here the weight at six years old) (see Table 6.8).

In this context, Katzina and Maturova (1989) noted that in the Tuva autonomous republic (an area at more northern latitudes, but an elevation of only 1 500 - 2 500 m) female yak reached fertile oestrous at approximately 90 percent of mature body weight compared with 60 percent for *Bos taurus* cattle in that region. First mating at the age of two years, though it also occurs in China, is more common among yak in some other countries (see Chapter 11, parts 2 and 3).

Breeding season

Yak are seasonal breeders. The onset and end of the period in the year when female yak come into oestrous is affected by climatic factors, grass growth and both latitude and altitude. When temperature and humidity start to rise, the ground begins to thaw and grass starts to grow. The female yak then improve in body condition and gain weight - following their long period of deprivation and weight loss over the winter - and they come into season. On the northwestern grasslands of Sichuan this occurs around June (Hu Angang *et al*., 1960). At the higher elevation of Nakchu prefecture in Tibet, the breeding season may not start until July. Similar observations are reported from Kyrgyz where it was noted, rather precisely, that the annual onset of the breeding season started on 25 May at an elevation of 1 400 m and became progressively later until at the altitude of 2 700 m oestrous started on or after 22 June (Denisov, 1958) - though it would be surprising if these precise dates applied to every year.

Zhang Rongchang (1989) summarized information from different sources on the effect of elevation on the time of onset of oestrus in yak. For example, at an elevation of 1 400 m yak started to show oestrus around 29 May; at 2 100 - 2 400 m it started 10 - 15 June; at 2 700 m it started 19 - 22 June; and at 3 000 - 3 800 m it started on 25 June. In Nakchu, Tibet, at an elevation around 4 570 m the yak only came to oestrus in early July.

The breeding season reaches its peak in July and August when temperature is at its highest and grass growth at its best. Thereafter, yak oestrous decreases in frequency and stops around November. Two sets of data on the onset of oestrous by month of year are summarized in Table 5.1; one set derived from the Datong Yak Farm in Qinghai province and the other from the Chovosol district in Mongolia.

Table 5.1 Oestrous in female yak according to month of year

Location	Percentage in oestrous from June to November[month]							
	[6]	[7]	[8]	[9]	[10]	[11]	No.	Source
Qinghai	3.5	21.7	28.7	18.3	15.6	12.2	115	Zhang Rongchang, 1979
Mongolia	5.5	12.1	41.2	14.3	6.7		342	Magash, 1990

The type of distribution shown in Table 5.1 is fairly typical of the general situation. Accordingly, if mating and conception do not occur, some yak may not return to oestrous in that season. Yak showing only a single oestrous in a season are not uncommon.

The vast majority of all mating takes place naturally between bull and cow at pasture (several bulls competing for the privilege - see section, Puberty and mating). For mating to other species of cattle, the yak cows are normally restrained (as they are also in some areas for mating to yak bulls). For mating to "improved" breeds of cattle (e.g. Holstein or Simmental), artificial insemination is now always used (as the bulls of these breeds do not adapt to the climate and altitude).

Signs of oestrous

Changes in the appearance of the reproductive organs are more obvious than behavioural changes, although these also occur (Luosang Jiangcuo and Chen Yu, 1987; Zhang Zhaowang *et al*., 1997). The vulva becomes swollen and the vagina reddens. Mucus is discharged from the vulva in a majority of females in oestrous, but a substantial minority show no such discharge. Vagina and cervix dilate, and the female tends to raise her tail and urinate frequently. As in other cattle, female yak in heat search out and ride other females and like to be approached by male yak - but these signs are less pronounced than in *Bos taurus* cattle. When a specific mating is required by the herder and mass mating is not practised, heat detection usually requires the use of a teaser bull. It is thought that the use of a teaser bull, on female yak in heat, will increase pregnancy rate following either natural mating or artificial insemination. Katzina and Maturova (1989) also make the point that signs of heat in yak are less obvious than in other cattle, and detection by herdsmen is unreliable.

Daily milk yield shows a dip during oestrous although this could not, on its own, be used to accurately indicate the presence of oestrous (Cai Li, 1989b). However, Yu *et al*. (1993b) have reported that the pre-ovulatory peak of oestradiol 17b and the progesterone profiles in both blood and milk are similar in yak to those observed in dairy cattle. Magash (1991a) has similar findings.

Time of day of oestrous

Most yak start their oestrous in the early morning or in the evening and only rarely at other times of day. Among 633 female yak on the Xiangdong Livestock Farm, Cai Li (1989a) observed that two thirds of the animals started to show heat before 0900 hours when they had started grazing, and most of the remaining third started after 1900 hours when grazing had ended for the day. Similar observations were reported by Lei Huanzhang *et al*. (1964). Magash (1991a) with records on 73 yak in Mongolia found, by contrast, that only 38 percent came on heat between 0200 and 0800 hours, and 34 percent between 1600 and 2200 hours. This still left a substantial remainder to show oestrous outside those hours - mostly between 2200 and 0200 hours.

Table 5.2, from yet another set of data, shows the distribution of oestrous of yak cows on the Datong Yak Farm. It is difficult not to conclude, from these various studies, that the location of the herd or other environmental factors help to determine the time of day at which oestrus starts.

Table 5.2 Distribution of oestrous according to time of day [Source: Zhang Rongchang, 1989]

	Time of day				
	0600-0900 hrs	**1000-1200 hrs**	**1300-1800 hrs**	**1900-2200 hrs**	**Total**
Number	35	6	14	20	75
%	46.7	8.0	18.6	26.7	100

Length of oestrous cycle

There is some variation in the length of the oestrous cycle from year to year. For example, the 1 184 observations by Liu Wulin and Liu Shengyu (1982) included in Table 5.3 were collected over a period of five years and showed that the annual mean length of the oestrous cycles varied from 19.2 to 21.6 days.

A feature of all the studies summarized in Table 5.3, except that of Yu *et al*. (1993a), is the large amount of variation among individuals. The coefficient of variation among these studies ranged from 16 percent to 41 percent. The reason for this is that oestrous in the yak is greatly affected by the environment. When the weather is unfavourable, the onset of oestrous is delayed; while in favourable circumstances, the onset of oestrous in female yak is advanced. The interval between heat periods can vary up to three-fold.

However, in different production systems there are reports of female yak capable of showing oestrous up to three to four times in the same season, as in the report of Katzina and Maturova (1989) for yak in the Tuva region, and Magash (1990) for yak in Mongolia, both referred to earlier.

Duration of oestrous

The duration of the oestrous period is not easily determined in the yak because the symptoms of oestrous are not always clear. Estimates from northwestern Sichuan suggest 12 - 16 hours (Cai Li, 1989a, b), while a report from yak in Shandan, Gansu province suggests 1.6 ± 0.8 days (Liu Wulin and Liu Shengyu, 1982). In a very small proportion of yak, oestrous may last four to five days, but one to two days is not unusual. Thus, a study with 41 well-fed and closely monitored female yak showed that 26 of them had an oestrous lasting 24 hours or less and three yak had oestrous up to 72 hours. More than 80 percent of these animals ovulated within 24 hours after the end of oestrous (Yu *et al*., 1993a).

Table 5.3 Various estimates of the length of the oestrous cycle (days)

Number of observations	Mean	[SD]	Source
1 184	20.5	5.4	Liu Wulin and Liu Shengyu, 1982
308	20.1	8.2	Liu Wulin and Liu Shengyu, 1982
53	22.5	5.4	Zhang Rongchang *et al*., 1979
12	18.3	6.1	TLRI, 1978
35	20.4	1.6	Yu *et al*., 1993a
90	19.1	(10 - 28)*	Katzina and Maturova, 1989
54	20.0	4.0	Purevzav and Beshlebnov, 1967
74	19.8	(10 - 27)*	Magash, 1991a

* Range

Zhang Zhaowang *et al*. (1997) reported a duration of oestrus of 12 - 48 hours for Tianzhu White yak. There is a tendency for the proportion of yak with heat periods of one to two days to increase later in the breeding season (August/September) when air temperature begins to decline. Katzina and Maturova (1989) reported an unusually long average duration of 3.7 days (from a range of 1 to 6 days) for yak in the Tuva region. In this context, it is interesting that the majority of their yak conceived in September. By contrast, Purevzav and Beshlebnov (1967) recorded substantially shorter heat periods in Mongolia. Among 54 Mongolian yak, 26 were noted to be in heat between only 0.5 and 6.5 hours, 17 yak in heat between 6.5 and 12.5 hours, 7 between 12.5 and 18.5 hours and only 4 yak with a longer oestrous duration. To account for some of the differences between the different studies, it is difficult not to conclude that the observational criteria of what constitutes the length of oestrous must vary among the studies.

Postpartum anoestrous

The average duration of postpartum anoestrous at the Xiangdong Livestock Farm in Sichuan province was found to be 125 days. That figure, however, was subject to much variation. At this farm, females that had calved did not usually show oestrous again in the year of calving (Cai Li, 1989b). The exceptions were cows, which had calved early in the season - before June - and which had acquired good body condition and good fat deposits over the summer. Postpartum anoestrous periods were found to be much shorter (70.5 [SD 18.5] days) for yak in good body condition than for those in a poorer body condition (122.3 [SD 11.8] days) (Liu Wulin and Liu Shengyu, 1982).

The anoestrous period following calving has been reported as related to the month of calving: 131 days, 124 days, 90 days and 75 days for females calving in March, April, May and June, respectively. (As reported earlier, only a few of the yak calving later in the season return on heat in the same year.)

Magash (1990) provided results on the interval between calving and first postpartum oestrous for female yak in Mongolia. These show clearly a relationship with month of calving - the earlier the calving, the longer the interval. However, in these results there was a considerable amount of variation around the average intervals. The results of Magash are shown in Table 5.4.

Table 5.4 Interval between calving and first postpartum oestrous in yak according to month of calving [Source: Magash, 1990]

Month of calving	Number of animals	Interval (days)		
		Mean	Range	SD
March	38	120.5	69 - 188	25.3
April	87	96.1	59 - 172	36.3
May	69	75.4	40 - 145	29.1
June	21	53.6	30 - 106	21.6
Overall	215	90.2	30 - 188	34.9

In the same study, Magash (1990) reported that, as might be expected, the service period following calving (on average only eight days longer than the oestrous interval) showed a very similar seasonal pattern to that seen in Table 5.4 for the interval between calving and first postpartum oestrous. Magash (1990) also showed for Mongolian yak that the interval between calving and the first postpartum oestrous was longest in cows that had calved only once (around 120 days) and that it then declined to its lowest interval in females between fifth and seventh calving (around 85 days) and increased again thereafter for older cows. Wang Minqiang *et al*. (1997) reported a calving interval of 459 days in a study of 439 parities of 161 cows on the Datong Yak Farm. This interval, they observed, was 25 - 48 days shorter among the cows of third to sixth parities than the interval for cows of both the earlier and later parities.

Erdenebaatar *et al*. (1997) attempted to shorten the interval to postpartum oestrous in the cows that had calved early in the year (from May to June) by various hormone treatments given early in the postpartum period (around 24 - 32 days after calving). But the results were not as expected, possibly due to failure, it was thought, of the activating hypothalamic-pituitary axis to support follicle development.

Proportion of cows in oestrous and calving

The proportion of female yak that come into oestrous in any one season depends on the previous calving history of the females as well as on their individual body condition. Female yak of reproductive age can be divided into three categories: those that have calved in the current year and are lactating and suckling a calf ("full-lactating yak"); those that calved in the previous year, are not pregnant but may or may not be still suckling their last calf (*Yama* or "half-lactating yak"); and those that previously had a calf but not for at least two years and are not lactating (*Ganba*).

On the Xiangdong Livestock Farm (from June to mid-September), *Yama* had the highest proportion of females in oestrous during that period (112/161), *Ganba* came next (217/408) and "full-lactating cows" had the lowest proportion (90/629) (YRO and XLF, 1983; Cai Li, 1989a). Similar observations were made by Zhang Rongchang (1979) in a study at the Datong Yak Farm in Qinghai (84.3 percent of *Yama*, and 36.6 percent of cows suckling a calf of the current year). Relative to the full-lactating cows with a calf at foot, the *Yama* and *Ganba* classes have had a better opportunity to recover from the drain on their body resources, consequent on calving and lactation, and more than 95 percent of them show oestrous (Ling Chenbang *et al*., 1982).

In ordinary production herds in the mountainous regions of China, a general average figure is that 50 - 70 percent of yak cows of suitable age show oestrous in any one year and that such female yak are mated and calve twice in three years, or once every second year. In one study, Cai Bolin (1981) found that 28.8 percent of Maiwa yak cows of reproductive age gave birth every year, 51.3 percent every second year and the rest, 19.8 percent, every third year. In another survey, by Lu Caijie (1982) in Tongren county, Qinghai, only 11 percent of yak cows gave birth every year, 75 percent twice in three years and 14 percent in every second year. The majority of yak in Damxung, Tibet calved every second year (Tang Zhenyu *et al*., 1982).

Use of hormones to induce oestrous

Various studies have shown that oestrous can be induced in yak and that the reproductive rate can be increased by that means. For example, at the Xiangdong Livestock Farm, Cai Li (1980b) gave an intramuscular injection of an analogue of LRH early in August - approximately one month after calving had ended - to induce oestrous in yak cows that had calved and were nursing a calf. Table 5.5 provides a summary of the results from the three-year investigation.

Table 5.5 Reproductive rate of yak cows with induced oestrous and normally occurring oestrous (control) [Source: Cai Li, 1980b]

Group	Year	No.	Calved next year (%)	Calved and surviving (%)
Induced	1976	120	30.0	30.0
	1977	120	90.0	84.2
	1978	110	73.6	73.0
Control	1976	722	42.8	40.0
	1977	871	45.2	44.9
	1978	914	53.4	53.3

The results from Table 5.5 show that the induction of oestrous by hormonal treatment, followed by mating, was not very successful in terms of calves born in the first year of the trial (1976). But the proportion of cows in which oestrous had been induced that then calved and the number of calves that survived to the end of the year had improved markedly in 1977 and 1978. (Calf survival was not, apparently, reduced by the increase in calving rate). Results of a study by Magash (1991a) with yak in Mongolia agree in showing, albeit on much smaller numbers of animals, that the oestrous rate in female yak can be increased by hormonal induction, compared with untreated controls. But, in his trial, there was, generally, a reduced conception rate following artificial induction of oestrous (similar to the result in 1976 of Table 5.5). Thus, following a single hormonal treatment, the conception rate recorded by Magash was around 56 percent compared to 75 percent in the controls. Following two hormonal treatments, the conception rates in the treated and control groups were 78 percent and 86 percent, respectively. In another report, Magash (1991b) noted also that the success of oestrous induction increased from June to August, approximately doubling over that period (the actual oestrous rates depending on the method of induction). This is analogous to the increase in oestrous rate, which occurs naturally over that period, as was noted earlier (Erdenebaatar *et al*. 1997).

Other researchers at various locations in China have used different hormonal treatments to induce oestrous in the yak. These trials have shown, for the most part, that the onset and timing of oestrous can be controlled in the yak, as in ordinary cattle species (e.g. Shao Binquan and Zhao Yanben, 1984; Yang Tingyou, 1984; Liu Zhiyao and Shuai Weiwen, 1985; Shao Binquan *et al*., 1986; Yu and Liu, 1996). The use of triple hormone injections was usually the most effective in these experimental situations. In one set of trials, Chinese traditional medicine ["injecting Herba Epimedii compound"] (Ma Tianfu, 1983) produced an increase in the number of animals on oestrous compared with the control group (44 percent vs. 18 percent).

Zhang Yun (2002) reported that among 80 yak cows synchronized for oestrus by different hormonal treatments, 62 showed oestrus within seven days. Seventy-six of these cows were inseminated by A.I. and 54 of them (71 percent) became pregnant, though only 44 of them calved. From a study in Mongolia, Magash (1997) reported that oestrus synchronization was achieved by using the PGF2-a alone. Davaa *et al*. (2002) used four different treatments to induce oestrous: PGF2-a, progesterone sponge, PMSG and FSH - but with only small numbers for the last two. Overall, 28 (53 percent) of the 53 cows and 8 (31 percent) of the 26 heifers showed synchronized oestrus. These authors also pointed out that the success of synchronization and of subsequent conception were both markedly affected by the body condition of the animals - the better the condition, the better the success of the treatment. Other factors, such as age of cow, interval after calving and the type of hormone preparation, also influenced oestrus induction. (In this trial, the FSH treatment [four cows and four heifers] appeared to be the least successful of the four treatments.)

A general comment on reproduction in yak

From the evidence just presented, the conclusion might be drawn that the yak is reproductively poor - calving relatively late for the first time and not regularly thereafter. This, however, is entirely a description of the situation prevailing in the high mountainous regions and the high mountain plateau where the vast majority of the world's yak are found. It has to be borne in mind that in these regions, with a short summer growing season followed by a harsh, prolonged winter, there is a severe shortage of feed for the animals over several months, coinciding with the time when cows should be pregnant. The lack of sufficient feed over winter leads to loss of weight and body condition, both often severe, in the female yak. These substantial losses are only made up over the next summer season - provided that the summer is not marred by lack of rain. It is highly likely therefore that the principal reason for variation in the age of the first onset of calving and the subsequent frequency of calving is due to variation in the nutrition of yak cows over the winter period. Evidence from the effects of supplementary feeding trials supports this. Further evidence is deduced from the reported reproductive rate of yak in North America (see Chapter 11, part 3). The yak there, although a relatively small population, are given sufficient hay and other feed throughout the winter to eliminate weight loss. The majority of such female yak will then breed for the first time a year earlier than in traditional yak territories and thereafter calve annually. Under the conditions of the traditional yak regions, such supplementary feed may, of course, be neither available nor cost effective, even if it can be procured (but see also Chapters 8 and 14). The point needs to be made that the relatively poor reproductive record of the yak, compared to, for example, dairy or beef cattle elsewhere, is not a consequence of heredity but of environment. The ability to induce oestrus by hormonal treatment, as shown by the results presented earlier, is clearly of interest. As also shown, however, body condition affects those results. More investigation is certainly needed to discover whether conceptions thus induced, in the absence of adequate winter nutrition, might not further exacerbate the problems of yak reproduction in subsequent years.

Gestation and parturition

Pregnancy rates

Conception following mating at first oestrous of the season is generally high. Among 68 female yak on heat, Cai Li (1989a) found by rectal palpation that 53 of them had well-developed follicles and 15 did not, due to diseased reproductive organs. In a trial (Liu Zhengkui, 1981) with 265 yak that had calved previously, 72.4 percent became pregnant following the first oestrous of the season, another 23.4 percent following the second, and 3.4 percent and 0.8 percent following the third and fourth cycles, respectively. Zhang Zhaowang *et al*. (1997) observed a 76.5 percent (727/950) conception rate to a single service in Tianzhu White yak. In an investigation with 342 yak in Mongolia, Magash (1990) found that 70.5 percent were pregnant after a first service, 19.3 percent conceived to a second and 4.6 percent to a third service, giving an overall pregnancy rate of 94.4 percent. It appears in that part of Mongolia, at least, that yak which do not become pregnant at a first service are able to return to oestrous up to three times in the same season, as already referred to earlier. Conception to first service improved as the breeding season advanced, and was best in September.

In one particularly well-maintained group of yak on grassland in Gansu province where the yak had also been given some supplementary feed in late winter and early spring, a conception rate of 94.3 percent was achieved (Yu *et al*., 1993a). A pregnancy rate of 74.9 percent, following insemination with frozen semen at first oestrous of the season, has also been recorded by Cai Li (1989b) in trials with 621 yak.

Many studies, in addition to those quoted, have shown that once mating has occurred, whether naturally or by artificial insemination, pregnancy rates above 70 percent in female yak are not uncommon, provided matings have been to yak bulls (Table 5.6 and also: NIAVS and Datong Yak Farm, 1965; Du Fusheng, 1981, 1987a, b; TLRI, 1978; Luosang Jiangcuo and Chen Yu, 1987). There is, however, a marked difference between pregnancy rates resulting from pure-breeding of yak and those from hybridization. When the yak female is inseminated with semen (or mated by a bull) of other species of cattle, antagonisms appear to arise and the pregnancy rate falls. As apparent from Table 5.6, the proportion of calves born and surviving was more than halved when yak cows were mated to *Bos taurus* bulls. The situation was even worse, and dramatically so, when A.I. was used with semen from such bulls - only three calves survived from the 217 such cows initially available for service. A combination of circumstances led to this disappointing result, including in this particular situation poor detection or occurrence of oestrous, poor conception rate and high loss of foetuses from the few pregnant cows. It is possible that advances in methods and AI technology (Zhang Rongchang, 1979; Ling Chenbang *et al*., 1982; Li Shihong, 1985), developed since the time when the trial recorded in Table 5.6 was conducted, might have led to an improvement on that situation.

Data from the Datong Yak Farm in Qinghai province where semen from Hereford bulls was used by A.I. to inseminate 117 yak showed a conception rate of 43.6 percent from 1975 to 1978 (Zhang Rongchang, 1989). Similarly, frozen semen of cattle was used for A.I. with yak in Hongyuan county of Sichuan province and the average conception rate was 44.9 percent (12 526 yak) with some variation over the years and, on average, 25 percent of the cows mated ended up with a surviving calf (Table 5.7).

Table 5.6 Effect on success of mating, conception and calving in yak cows of different types of mating [Source: YRO and XLF, 1983, 1984]

Mating of yak female*	No. females of breeding age available	Mated (%)	Conceived of those mated (%)	Foetuses lost of those pregnant (%)	Calving of those pregnant (%)	Cow with surviving calves of those pregnant*** (%)
Yak male - natural service	323	51.1	87.3	11.1	88.9	36.8
Bos Taurus male - natural service	59	52.5	54.8	41.2	58.8	16.9
Bos taurus male - A.I.	217	22.1	25.0	66.7	33.3	1.4
Yak male - natural service after failure of A.I.**	205	47.3	93.8	3.3	96.7	39.5

* Natural mating to yak bulls: July-October; A.I. with *Bos taurus* semen: July-August; re-mating, to yak bulls, of cows which failed to conceive to A.I.: September-October.

** Note months of re-mating (see above).

*** Calves surviving to six months of age.

Table 5.7 Conception and calving in yak cows serviced by A.I. with frozen cattle semen in Hongyuan county of Sichuan [Source: adapted from Liu Shenqing, 1989]

Year	No. of females mated	Conceived of those mated (%)	Foetuses lost of those pregnant (%)	Calving of those pregnant (%)	Cows with surviving calves of those pregnant (%)
1976	275	48.0	21.2	67.4	65.2
1977	798	45.5	22.3	77.7	69.1
1978	3 774	39.9	17.6	81.0	69.6
1979	2 841	44.8	23.0	82.4	77.6
1980	3 212	51.9	26.3	73.6	68.5
1981	1 626	46.2	16.1	77.0	69.2
Total	**12 526**	**44.9**	**20.7**	**78.0**	**71.6**

Effect of age and physiological state

The three types of female categorized in terms of their current and previous calving history differ in pregnancy rate (see Table 5.8 and also: Ling Chenbang *et al*., 1982; Cai Li, 1989a). The age of the female also has an effect, with five- to six-year-old females being the best, on average, although not by a large margin. By the age of nine to ten years the conception rate starts to fall away. Some results are shown in Table 5.8.

(An explanation is required in respect of the youngest age group - the yak females aged three to four years old [this includes the summer following their fourth birthday when, strictly, the females may be four and a half years old]. Some of these animals will have calved previously at two or three years of age - that is the relatively small proportion of yak females that had achieved this because of particularly good body condition and other favourable circumstances earlier in their life. If they had not become pregnant again after their first calving, they were also categorized as *Yama* or *Ganba*, even though they were only three to four years old.)

Table 5.8 Conception rate of three types of yak female according to age

Type of female	**3 - 4 years**		**5 - 6 years**		**7 - 8 years**		**> 9 years**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Yak cow with calf*	11	9.1	27	11.1	39	7.7	15	13.3
Yama**	52	30.8	135	39.3	117	45.3	82	40.2
Ganba***	53	22.6	436	22.2	537	18.8	308	14.6

* Yak cow nursing calf born in current year.
** Yama = cow calved in previous year - with or without calf.
*** Ganba = cow that has calved, but not for at least two years.

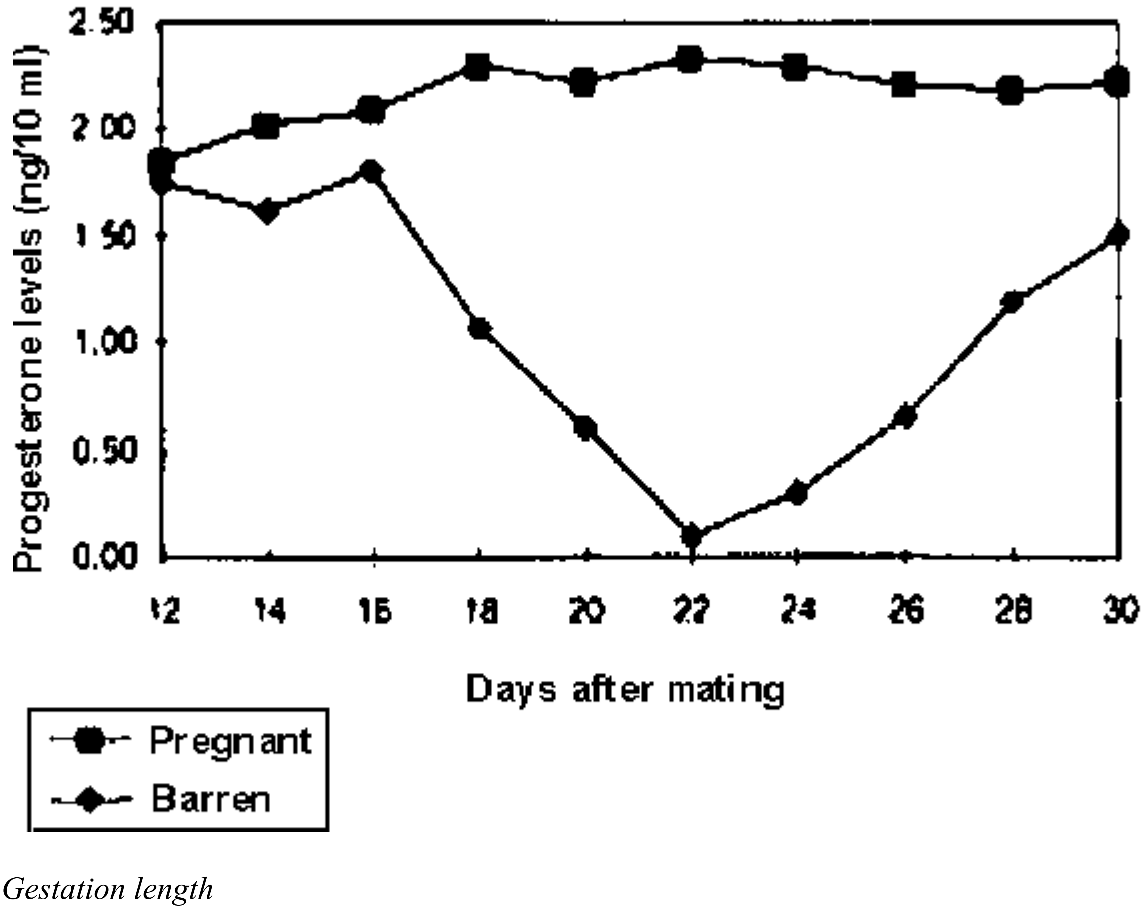
The gravid uterus

Cai Li (1980a) dissected the reproductive organs of 38 female yak on the Xiangdong Livestock Farm (Sichuan), 17 of which had been pregnant between one and four months. Eleven of these 17 had the foetus implanted in the left uterine horn and six in the right. The size of the ovary and the oviduct on the side of the gravid horn was substantially larger. However, the maternal caruncles and cotyledons were about equally developed in both uterine horns. Up to one and a half months after conception, the gravid and empty horns had the same diameter; and up to that time the foetal placenta can invade both horns equally. Thereafter, the septum dividing the horns becomes indistinct and disappears as the foetus grows. The gravid horn sinks below the pelvic brim after two months of pregnancy. In early pregnancy, diagnosis of pregnancy by rectal palpation depended mainly on the size and shape of the two ovaries and on changes in the shape of the septum.

Mohanty *et al*. (2002) at the National Research Centre on Yak in India examined 16 placentas immediately after their expulsion following the birth of the calf and found that the average placental weight was 1.6 ± 0.5 kg and the total numbers of cotyledons in pregnant and nonpregnant horns were 45.0 ± 7.1 kg and 27.3 ± 4.1 kg, receptively. Total cotyledon area was 1494 ± 327 sq cm and the average calf birth weight was only 12.4 kg, giving a ratio of total cotyledon area to birth weight of calf of 123.0 ± 23 sq cm per kg. The authors suggested that malnutrition in the third trimester of pregnancy seems to be the major cause of low calf birth weight and low placental weight.

As in other cattle species, the progesterone level in milk increases during gestation, but in mid-cycle it falls greatly in barren cows (see Figure 5.2). Progesterone level can therefore be used in pregnancy diagnosis in yak and with a high degree of accuracy between about days 18 and 24 after mating (Xue Liqun, 1983; Magash, 1991b). Yu *et al*. (1993c) confirmed a rapid rise of progesterone levels both in blood and milk of yak starting around day two of pregnancy.

Figure 5.2 Progesterone levels in milk of 15 pregnant and 8 barren yak females between 12 and 30 days after mating [Source: Xue Liqun, 1983]



Gestation length

The gestation length of female yak is shorter than that of *Bos taurus* cattle, particularly when a pure yak calf is carried. Female yak bred pure have, on average, a shorter gestation length than when carrying a F1 hybrid calf. For yak with pure-bred calves, Denisov (1938) reported an average gestation length of 258 days; Lei Huanzhang *et al*. (1964) recorded an average gestation length in 36 yak of 260 days (range 253 - 278 days) for those carrying male calves and 250 (226 - 283) days for those with female calves on the Datong Yak Farm. Dubrovin (1992) reported an average gestation length of 258 days for 800 yak cows in the Caucasus; Katzina and Maturova (1989) noted an average gestation of 259 days (228 - 280 days) for yak in the Tuva region; and Yu *et al*. (1993) reported an average of 254 days [SD 2.7 days, a range of 248 - 258 days] for yak in Gansu province. Joshi *et al*. (1994) gave an average of 258 days for the gestation length of yak in Nepal.

The average gestation length of yak cows with F1 calves (cattle bull mated with yak cow) was found by Cai Li (1989a) to be around 270 days (273.2 with a SD of 12.7 days for 371 cows with male F1 calves and 268.6 with a SD of 10.2 days for cows with female F1 calves). In Cai Li's study, the breed of bull used also appeared to affect gestation length. This also was noted by Zagdsuren (1994) for yak in Mongolia. Denisov (1938) recorded an average gestation length of 276.2 days for female yak mated to Schwyz cattle.

On the Datong Yak Farm, the average gestation lengths of yak cows carrying male and female hybrid calves sired by the Hereford were 277 ± 6.2 days and 261 ± 7.6 days, respectively (Zhang Rongchang, 1989) and longer for yak cows with pure yak calves (260 days on the Datong Yak Farm; Lei Huanzhang *et al*., 1964). The longer gestation lengths for the hybrid calves are associated with substantially higher birth weights relative to pure yak calves (cf. Li Kongliang *et al*., 1989) and this, in turn is a cause of an increase in dystokia when yak cows carry hybrid calves (see the parturition section that follows).

The wide range of gestation lengths quoted by some authors seems surprising, as do some of the differences among studies. The wide ranges, when not otherwise stated, will include the differences in gestation length attributable to sex of calf and any differences that may be associated with age of dam (though none such are reported). It is also possible that there are differences attributable to breed of yak, which would be, in these circumstances, usually confounded with location (although, again, there are no specific reports of breed differences in gestation length for the yak, though such differences are documented for other types of cattle). In order to explain some of the more protracted gestation lengths, one must perhaps wonder whether both females with yak calves and those bearing inter-species hybrid calves are included together in the ranges, although this is not apparent from the reports. These considerations would still leave unexplained the very short gestation lengths reported at the lower end of the range. The problem with the ranges quoted is that they provide no clue to whether the extreme values are isolated cases and might include premature parturition.

Parturition

Almost all births take place during the day and only very few occur at night when the yak cows are normally at the herders' campsite. When the time for parturition approaches, the female yak looks for a sheltered spot, such as a depression in the ground or a ditch, at a distance from the herd. Typical behaviour of the yak during labour includes lying on her side and standing up again for delivery when a pure yak calf is carried. When a hybrid calf is carried, the female will deliver the calf while lying on her side - presumably on account of the larger size of the calf and the longer time needed for the delivery (Cai Li, 1989b).

Dystokia is a rare occurrence in female yak with pure-bred calves; for example, in Gannan, Gansu, it was only 1.8 percent among 1 929 yak cows (Lu Huaijiang, 1995). Normally, herdsmen offer no assistance. The umbilical chord is broken by the act of mechanical stretching as the cow gets up or the calf falls down after delivery. Inflammation of the chord is rare. Yak cows with hybrid calves, however, require help for delivery and dystokia occurs to some extent. For example, there were 28 cases among 861 such calvings (3.3 percent) over a period of ten years in one study in Sichuan. In another study, Yuan (1991) reported that 20 out of 63 yak cows that were carrying Holstein hybrid calves retained their afterbirth, whereas normally such retention is less than 5 percent in yak.

Zhang Rongchang (1989) suggested that to reduce the incidence of dystokia it might be helpful, when producing hybrids, to use the yak cows of larger body size, with well-developed rump, which had already calved in previous years. As found in studies with cattle elsewhere, it appears that the relationship of calf size at birth to maternal size may be a critical factor in dystokia.

Twins are rare in yak; in general, they account for about 0.5 percent of all births, though higher rates have been recorded occasionally.

Behaviour

The dam generally licks the newborn calf for about ten minutes, after which the calf attempts to stand up and suck. Again, differences in behaviour have been observed between dams delivering pure-bred yak and F1 calves. Some results are presented in Table 5.9. They show that time intervals are markedly longer when a F1 calf is involved than when pure yak calves are born.

Table 5.9 Intervals between successive events at parturition according to type of calf [Source: Qi Guangyong, 1984]

Nature of events	**Interval (range in ′ minutes and ″ seconds) between events**	
	Pure yak calf	**F1 hybrid calf**
Appearance of calf to end of parturition	3′ - 6′	45′ - 107′ (with help)
Calf out to calf being licked	0′2″ - 0′5″	0′3″ - 0′7″
Calf out to calf starting to stand up	14′2″ - 21′30″	60′0″ - 99′14″

Calf out to first sucking	15′ - 22′	74′ - 103′
Duration of first sucking	3′0″ - 5′30″	5′32″ - 11′21″

In a more recent study, Zhang Zhaowang *et al*. (1997) found in Tianzhu White cows that parturition was completed in 3 - 40 minutes and that the newborn calves stood up for suckling after about 20 - 30 minutes - both periods somewhat longer than in the study shown in Table 5.9. The placenta is ejected usually between half an hour and six hours after parturition

In the period shortly after birth, the dam is intensely protective of her calf and will attack any person coming close. She may not, however, do so directly. For example, the dam may retreat, as though afraid of the person, and then attack from the side or from behind. This is a time for people to take special care! (Cai Li, 1989b)

Bonding of dam and calf depends mainly on smelling and licking. Longer times of parturition and dystokia militate against such bonding and thus place F1 calves at a disadvantage to pure yak calves - at least on average. Yak cows can distinguish their calves by smell from among quite large groups of calves.

Calving season

The calving season is obviously connected with the time in the previous year when oestrous and mating occurred and is therefore prone to the same environmental and physiological constraints. Table 5.10 shows the distribution of calving from March to August at various locations.

On the basis of the distribution of the month in which yak cows in Mongolia were mated, as Magash reported by (1990), it can be estimated that a small proportion of the yak cows calved in March, probably around 25 percent in April, many more than that in May, the peak month, and a declining number in June and July.

Table 5.10 Percentage distribution of calving in different months of the year at different locations

Location [source]	No.	Mar	Apr	May	Jun	Jul	Aug
Qinghai - Datong[1]	155	12.3	39.3	24.5	15.5	8.4*	
Qinghai - Datong[2]	137	4.4	39.4	33.6	18.2	2.9	1.5
Gansu - Zhangxian[3]	98	20.4	24.5	27.6	21.4	6.1	
Sichuan - Ganzi[4]	34		17.6	35.3	41.2	5.9	
Yunnan - Zhongdian[5]	34		8.8	26.5	38.2	23.5	2.9

* Including August.
Sources: [1] Lei Huanzhang *et al.*, 1964; [2] Liu Zhengkui, 1981; [3] Xiong Zaiyue, 1982; [4] Hu Angang *et al.,* 1960; [5] Jiang Ruisheng and Bai Yinhua, 1985.

Denisov (1958) reports from (what was then known as) "Kirgizia" that the calving season for a herd of 597 yak extended from February to December but with only five calves born in February, rising to 116 in March, 253 (42.4 percent) in April and 113 in May, with numbers tailing off rapidly thereafter.

When hybridizing yak to produce F1, it is common practice to attempt the hybridization - irrespective of whether by natural mating or A.I. - in the first half of the breeding season and to follow this by the use of yak bulls, to catch cows that have not conceived and have returned on heat. Thus, it is not unusual for the hybrid calves to be born earlier in the season than the pure-bred ones.

Calf survival - prenatal and postnatal

Abortions and other causes of premature termination of pregnancies account for perhaps 5-10 percent of all pregnancies, as was shown in Table 5.6 with observations from Sichuan. A similar incidence was reported from observations on 971 female yak in Nagqu, Tibet with an abortion rate of 5.4 percent, and a rate of 5.2 percent among 1 929 yak cows in Luqu, Gansu (Lu Huaijiang, 1995). On the Datong Yak Farm, Qinghai, 85.9 percent of 2357 pregnant yak cows calved normally (NIAVS and Datong Yak Farm, 1965).

As already indicated, the normal calving rate is lower when interspecies hybridization is carried out. Among 1 348 such yak cows (carrying hybrid calves) in northwestern Sichuan, 20 percent lost their calves during pregnancy and, in another study with 158 young pregnant yak females, 14 lost their hybrid calves before normal parturition (Ling Chenbang *et al*., 1982). Calf survival is generally high when the calves are allowed to suckle and the dams are not milked, but survival can fall greatly when the cows are also milked, as shown in Table 5.11.

Table 5.11 Survival of calves according to rearing method [Source: Wu Derun and Ma Juru, 1985]

Rearing Method	No. of cows	Calves born (%)	Calves surviving of those born*** (%)	Reproduction rate*** (%)
Dam milked*	1 366	66.0	57.9	38.2
Dam not milked**	2 542	81.1	93.7	76.0

Year of records: *1975 - 1976
**1977 - 1979

***of cows mated with calf surviving to six months old

Since the two rearing methods were conducted in different years (Table 5.11), it is possible that a year effect might have affected the results. The apparent difference between the groups in the proportion of calves born is difficult to explain unless it is a "random" year effect, or unless it is a carry-over effect from the previous year. Such an effect could have arisen if the herder's decision to milk or not to milk is repeated across years so that cows milked in the current year were also those milked in the preceding year, and those not milked were also not milked in the year before (information on this point is not given). It would be surprising if a year effect negated the large rearing effect on calf survival after birth, as similar results to those shown in Table 5.11 have also been obtained in other sets of observations (NIAVS and Datong Yak Farm, 1965; GAAHB and YRO, 1980).

A 90 percent survival rate is typical for pure-bred calves, e.g. 1 328 out of 1 470 calves surviving among Jiulong yak in Sichuan (Cai Li, 1989b), and 1 818 out of 2 025 pure-bred calves on the Datong Yak Farm, Qinghai (NIAVS and Datong Yak Farm, 1965). In contrast to the greater problems before and during parturition experienced with F1 calves, the hybrid calves, once delivered, have a slightly better survival rate after birth than pure yak calves. Results at the same locations showed survival for F1 calves to be about 2 percent better than for the pure-bred calves.

Detailed observations (Ouyang Xi *et al*., 1984) on 20 yak calves on a farm at an elevation of 3 500 - 4 100 m showed that neonatal survival was also related to the maintenance of body temperature in the calf. The fall in temperature in the first hour after birth (average fall 0.38^{o}C) was significantly correlated (r 0.69) with birth weight (the greater the weight, the less the temperature loss) but much less strongly correlated with ambient temperature. Thus, the body condition of the dam during pregnancy affected calf survival through its effect on birth weight. The body temperature of the calves returned to normal, after three hours on average.

To maintain the temperature of cows and newborn, a simple greenhouse made from clear plastic sheeting has been introduced to yak-raising areas in Gansu, Qinghai and Tibet to keep the animals inside during the colder times of the day.

Other factors influencing reproductive efficiency and calf survival

Inbreeding effects

Chen Youkang *et al*. (1994a) studied the effect of inbreeding on reproductive efficiency in 70 yak cows. They found that in this experimental herd, the inbreeding coefficient went up from the base generation (taken as zero inbreeding) to 0.11 in generation 1 and 0.19 in generation two. The interval between generations zero and one was 1.82 years and that between generations one and two was 2.61 years. At the same time, calf survival went down from 94 percent to 81 percent respectively for the two generations. The decline in conception rate and increase in calf mortality, which together were responsible for a marked reduction in reproductive efficiency, was attributed to the increasing inbreeding. Inevitably, different generations are born in different years. Unless special measures are taken to create an overlap of generations within year, a year effect could be confounded with the inbreeding effect. The inbreeding effect, showing a decline in reproductive efficiency is, however, in the direction expected (see Chapter 3).

Supplementary feeding

Yak cows given supplementary feed during pregnancy showed a small increase in the number of calves born, probably through reduced embryonic loss, and a somewhat greater increase in calf survival. This result is derived from an experiment conducted at Longri Farm in Aba county of Sichuan (part of a project undertaken by the Southwest Nationalities College [now University] with support from United Nations Development Programme and FAO). Results from this trial will also be referred to in Chapter 6, in relation to growth and milk yield; the design is described here only in outline.

Three groups of females, equivalent to each other in all respects and which had previously had normal opportunities to mate, were allocated to three feeding regimes. One group was given hay from mid-December to the end of April. The amount eaten by the cows in mid-winter varied around 4 kg per animal per day, but the intake fell to less than 1 kg, on average, in April. This treatment was repeated for two years. A second form of supplementation was practised in the first of the two years by allowing a group of cows access to grass paddocks that had been closed off in the autumn. The yak in this group were allowed into these paddocks with standing wilted grass for 45 days from the beginning of April - the latter part of pregnancy for most of the animals. The third group of yak cows received no supplementary feeding and were subjected to the management normal for the area. This group acted as the control. The results, in respect to the number of calves born and calf survival, are shown in Table 5.12.

Table 5.12 Percentage of Maiwa yak cows calving and calf survival from three groups of cows [Source: Wen Yongli *et al*., 1993]

Year	Treatment group*	No. cows	Calving (%)	Calf survival (%)	Calves surviving Per 100 cows mated
1989/90	Hay	75	58.7	93.2	54.7
	Paddock grass	75	56.0	90.5	50.7
	Control	148	55.4	85.4	47.3
1990/91	Hay	58	64.4	92.1	59.3
	Control	150	60.0	85.6	51.3

* For details, see text.
a) fed hay from mid-December to end of April;
b) allowed access to conserved grass paddocks from 1 April for 45 days; and
3) unsupplemented, control group

In relation to the results in Table 5.12, it is tempting to suggest that the provision of hay may have stopped before the final stage of pregnancy, when foetal growth is at its most rapid. However, as indicated earlier, the cows began to eat less in the latter part of the feeding period as the first green shoots of grass started to appear on the pastures. Of course, the overall effect of feed supplementation cannot be judged by only the small increase, about 8 percent, in the proportion of surviving calves per 100 cows mated. Other effects, shown in Chapter 6, need to be considered. Unfortunately there is no information available on possible carry-over effects on the subsequent conception rate of the supplemented and control groups of cows. Results presented in Chapter 14 (Table 14.17) provide further evidence on the positive effects of supplementary feeding on reproductive rate and other aspects of performance.

Length of reproductive life

Exceptional female yak may live to an age of about 24 years, but 15 - 16 years is the normal upper limit for reproductive activity. The peak reproductive ability is considered to be between the fifth and the ninth year of life. Maiwa yak females reproduce normally for about ten years with a total of five to seven calvings (Cai Bolin, 1981) and Zhongdian yak cows showed their best reproductive performance between the ages of five and 11 years (Duan Zhongxuan and Huang Fenying, 1982). In one study by Ding and Chen (1994) 82 percent of females of reproductive age were ten years old or younger. Chen Youkang *et al*. (1994b) found five cows older than 20 years among 437 yak cows giving birth on the Xiaman Farm in Sichuan, but the survival of their calves was poor. Zhang Zhaowang *et al*. (1997) noted that the normal practice among herders of Tianzhu White yak is to use them for breeding up to the age of 15 years (see also Chapter 11, part 1).

Reproduction in the male

Male organs

The anatomical and histological structures of the genitalia of the yak bull are virtually the same as those of other bovine species, apart from the small, hairy scrotum - an adaptation to the cold environment (Qing Fufang *et al*., 1990, 1993; Xu Kangzhu *et al*., 1991). Pan Heping and Yan Ping (1997), Yan Ping *et al*. (1997) and Doyoddorji and Batbayar (1997) showed variously that the sizes and weights of testes and epididymis, as indicators of spermatogenesis, increased greatly from a young age right up to five years old. Doyoddorji and Batbayar (1997), for example, recorded that the weights of the right and left testes of 14 two-year-old Mongolian yak were 44.9 ± 3.6 g and 48.9 ± 2.9 g, respectively (similar to the weights of testes of 18-month-old yak in Pan Heping and Yan Ping's survey.). By the age of five years, the testis weights (from three bulls) were almost four times greater, and the epididymis weights had doubled. The Pan Heping and Yan Ping studies also included crosses between domestic and wild yak, but in terms of the sizes of testes and epididymis, or the increases in size, there was relatively little difference between the crossbred and the pure-bred males.

Puberty and mating

Age

Yak males start to show mounting behaviour around the age of six months, towards the end of the first warm season in the year of their birth. In the following year, this behaviour continues and intensifies to include searching for female yak and mounting them. No sperm were found in the epididymal fluid of yak bulls before the age of two years in a study by Wang Xiaoxin (personal communication, based on a research report of a former Northwest Animal Husbandry Institute, 1964). Thus, puberty normally occurs in the third warm season following birth, when the male is more than two years old. In practice, bulls start to mate from the age of three years or, more usually, four years onward, reaching their peak ability at around six to seven years old - after establishing their position in the mating hierarchy after four years in the same herd. After the age of eight years, yak bulls start to lose to younger bulls in the competition for females (see section, Breeding season). Cai Bolin (1981) noted that Maiwa yak bulls were used for mating from three years old onward and that their peak ability came around four to nine years old. Zhongdian yak bulls started to be used for mating when four years old and showed peak capacity between the ages of 5 and 11 years (Duan Zhonxuan and Huang Fenying, 1982).

A study of 38 yak bulls at an A.I. stud in Tibet (elevation 4 300 m) supported the belief that the sexually productive life expectancy for a yak bull does not exceed ten years. The Tibet study showed that the ejaculate volume and the concentration and motility of sperm in the semen rose steadily from the age of three to nine years and then declined (Zhang Yun, 1994).

A study by Magash (1990) provided interesting additional evidence from Mongolia on the changes in the mating activity of yak bulls in relation to their age. This is summarized in Table 5.13.

Table 5.13 Mating activity and success of yak bull in Mongolia according to age of bull [Source: Magash 1990]

Age of bulls (years)	Cows mated		No. of mounts per cow	Percentage of cows pregnant
	No.	(%)		
7	61	(43)	1.5	72.1
6	43	(30)	1.8	83.7
5	27	(19)	2.1	92.6
3	11	(8)	2.3	90.9
Total/average	**142**	**(100)**	**1.8**	**80.9**

The results from the Mongolian yak study (Magash, 1990) presented in Table 5.13 indicate that the older the bull (within the age range shown), the more females the yak bull was able to serve - consistent with the courtship behaviour and dominance hierarchy of bulls. Interestingly, the results also show that the younger bulls, with fewer females at their disposal, mount their mates more often. Thus, the three-year-old bulls mounted their mates half as often again as the seven-year-old bulls. It is also interesting that fertilization seemed to be more dependent on the number of services than on the age of the bull, in line with the pregnancy results of the same Magash study quoted earlier, which showed that the overall pregnancy rate of females increased with the number of services.

Behaviour

Bulls stay with the herd only during the breeding season. They spend winter and spring alone. Bulls can pick up the scent of females on heat at a distance of several kilometres - even 10 km have been reported.

Courtship behaviour

When with a herd of females, bulls will fight each other to obtain possession. Only the strongest attain the dominant position in the herd and such bulls have the most mates (as the oldest but virile group did, shown in Table 5.13). However, other strong bulls will also get an opportunity to mate cows, though in smaller number. Old, feeble bulls retain no mating position in the hierarchy of the herd. They then no longer try to mate and leave the herd. Young bulls do not usually win a place in the competition for mates until they are four years old and then only after some experience of fighting in the previous year. (Yak bulls in Mongolia, as judged from the results in Table 5.13, are apparently more precocious and reach that stage a year sooner). Such competition among bulls, to the extent that it introduces an additional element of natural selection, must provide the yak with some advantages in surviving in an unfriendly environment. By also ensuring that old bulls are replaced, generally before their daughters in the herd have reached breeding age, this competition for dominance may also have a role in reducing the chance for inbreeding to occur.

The extent to which inbreeding is avoided must be uncertain, as there is nothing other than human intervention to prevent bulls from mating their siblings or from bulls being succeeded in the herd by their sons.

Mating behaviour

Yak bulls get very excited sexually. Those that have won a mating position in the herd will mate several times a day. The bulls are so intent on mating that when in the process of doing so they will not attack other bulls, unless strongly provoked. It would be interesting to have information on the extent to which dominant bulls, which mate frequently, lose body condition as a result of their sexual activity over the mating season. This is known to occur in some wild animal populations (e.g. deer) and when it happens, it gives less dominant males the chance to mate.

Artificial insemination

Training

Yak bulls can readily be trained to provide semen for artificial insemination, and, once trained, they will retain this capacity into the next breeding season. The bulls can be taught, in as little as seven days, to mount dummy cows and supply semen into an artificial vagina (Du Fusheng, 1987a, b; Li Kongliang *et al*., 1986; Zhang Yun, 1997). More detail is given in Chapter 8.

Semen quantity and quality

Volume and quality are generally considered good. In one trial with more than 14 collections (Du Fusheng, 1987), the average volume was 2.4 ± 0.9 ml with average sperm density of 2 680 ± 590 million per ml, motility of 0.82 ± 0.05 and a malformation rate of 8.3 percent (6.3 - 10.4 percent). The yak semen retains good fertility after diluting three-fold for fresh use and after pelleting and frozen storage.

Liu Hui *et al*. (1993) reported that the daily sperm yield in yak bulls is about 4.66 ± 0.47 x 10^9. This is lower than reported for *Bos taurus* cattle but higher than for zebu cattle (*Bos indicus)*.

The densities referred to above are more than twice those reported by Zhang Yun (1994) from a station in Tibet (at an elevation of 4 300 m) producing frozen semen from yak bulls (the density values shown are also higher than those usually quoted for bulls of the "improved" cattle breeds [300 - 2 000 million per ml according to a review by Setchell, 1993] although the volume of ejaculate in such bulls is usually greater than in the yak). The sperm concentrations (per ml) reported by Zhang Yun (1994) were in the range 740 - 1 210 million per ml depending on the month of year and the age of bull. Ejaculate volume in these bulls varied with month and age, from 1.2 ml (in March) to almost 3 ml (in August) and from 2 ml in three-year-old bulls to 3.3 ml in nine-year-old bulls. Semen quality was also at its best from the nine-year-old bulls, and in the month of August in that part of Tibet.

Relations with other cattle species

When left to their own devices, yak cows do not allow bulls of other cattle species to approach them, and yak bulls show no inclination to mate cows of other cattle species. The reluctance to mate across the species has been reported from a number of different regions, as, for example, by Bonnemaire and Teissier (1976) in their studies from Nepal.

When forced to graze in herds of mixed species, the antipathy of the yak to members of the opposite sex from the other species of cattle declines, though it may not disappear altogether. When bulls of both species are present at the same time in a herd, a yak cow on heat will only allow a yak bull to mate with her. Bulls of the other species do not win in any competition with yak bulls for yak females.

In situations where a yak cow has been mated by a bull of another species and is then served again by a yak bull in the same oestrous period, the calf is almost always pure yak and not a hybrid - suggesting a preferential fertility for the yak sperm. Thus, to obtain hybrid calves, the yak cows must be kept with the bulls of the other species, and access to yak bulls has to be prevented. One way of doing this, as referred to earlier, is to restrain the yak cow in a mating crate and then allow her to be served by the bull of choice or by artificial insemination.

As was noted in Chapter 3, wild yak bulls readily mate with domestic yak females and produce wild-with-domestic crosses. In this case, there is no preferential fertilization from domestic yak bulls when they are present in the same herd alongside the wild yak bulls.

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6 PRODUCTION CHARACTERISTICS OF YAK

Overview

Growth

Rapid growth of the yak calf in the first few months of its life is a prerequisite for survival over the first winter and for a good start to its continuing growth in the following year. Thus, animals that are born early in the warm season have a better chance than those born later. Calves with exclusive access to the milk of their dams have the best opportunity for growth, especially if they are allowed to graze at night alongside their dams - but such night grazing is not common practice. Calves with dams that are milked once daily generally grow appreciably better than those with dams milked twice daily, not only because they have a somewhat greater milk intake but because they have perhaps an extra four to five hours daily available for grazing alongside their dam. Males become heavier than females, but they grow relatively more slowly in the early years of life and continue to grow for longer. Typically, in China, males are brought into the adult herd at six years old and females at four years; but in some other countries this occurs a year earlier. Breeds of yak appear to differ in size and growth rate, though this observation is usually confounded with differences in location. There is much seasonal variation in body weight.

Heavy losses in weight over winter and spring are recovered during the following warm season, when young animals recover what they have lost and make all their additional growth. This pattern is repeated each year. Approximately 25 percent of the weight at the end of the warm season normally is lost over the succeeding winter and spring - except in the first year of life when that loss is only about 12 percent. Linear body dimensions of the animals reach their final size at an earlier age than does body weight - although there are differences among the dimensions in age at maturity. As must be expected, the linear body dimensions show less seasonal variation than does body weight.

Milk production

Milk yield in yak is low and seasonal. The amount produced is only what would normally be needed for the good development of the calf. However, as milk is an important product for the herdsmen, milking is done at the expense of the calf - though once-a-day milking has relatively little adverse effect on calf growth compared with twice-a-day milking. There are reported differences in milk yield among breeds, but these are breeds kept at different locations. There are no specialized milk strains of yak. Though the milk yield is low, the solid content, and fat in particular, is high (6.5 percent is not uncommon).

The single most important factor influencing milk yield is the supply and quality of grass in the warm season of the year. Daily yield most often reaches its peak in August. Supplementary feeding, though effective in maintaining yield out of season, is not practical or economic under most present conditions.

Yak do not dry off when milking ceases at the end of the warm season, and the calf, when present, continues to take some milk. Lactation can continue into a second year without pregnancy recurring and reach between one half and two thirds of the yield in the year of calving. The yak does not readily let down its milk without stimulation from the calf, and milking is quite strenuous because of the strong sphincter muscles in small teats.

Meat production

Yak meat is obtained mostly from animals that are surplus to other requirements. Surplus males are castrated - usually at a fairly mature age - and slaughtered as steers. Meat quantity is determined largely by body weight. Animals are normally slaughtered in September or October when they are in the best and fattest condition.

Dressing percentages commonly range from around 45 percent to 58 percent, the ratio of lean to bone from as little as 3:1 to as high as 6:1, depending on the source and condition of the animal. The fat content of the carcass and the fat content within the meat are generally low.

Fibre production

Hair is an important by-product of the yak. Quantity produced varies with the age and size of the animal, with breed and sex and with the method of harvesting. There are two distinct types of fibre - down fibre and coarse hair - differing in diameter, length, degree of medullation and other properties; there is also an intermediate "mid-type" hair. The proportions of the different types of hair vary on different parts of the yak body. The proportion of down fibre is high in calves and declines as the animal gets older. Down fibre grows as additional protection for the yak over winter and has to be harvested prior to being shed in the early summer. The down fibre is much valued for textiles.

Hides

Large numbers of hides are produced and processed, but quality is not regarded as good as from other cattle. Weights of hides vary with but represent around 6 percent of live weight. Thickness of skin varies with the age of the animal and the part of the body.

Draught performance

Yak steers are used widely for carrying packs, for riding and, in some areas for cultivating land. Yak have high endurance for work and can carry heavy loads in relation to their own body weight. They are particularly valued for their ability as pack animals to cope with dangerous terrain and marshy land at high elevations.

Improvements in production

Interventions in breeding, animal and herd management, feeding, housing and pasture management can all be used to try to improve output. However, it is important to ensure the cost-effectiveness of such measures.

There are approximately 12 million yaks in China which is about 85%of the world total making China the leader for Yaks.

Yaks are located mainly in the high, cold mountainous areas of China.

Yaks can graze on the alpine grasslands in the summer and duringwinter on the shrubs in deep snow in rigorous temperatures. The yak loosesweight during the winter but recovers and gains weight rapidly with thecoming of spring grass.

The yak's long coarse hair acts as insulation for their body. Theanimals also grow a dense woolen undercoat for winter protection.

Research workers claim there are three types of yak in China. Theyare:

- Valley: mainly distributed inthe valleys of North and East Tibet, as well as in some parts of Sichuanand Yuman provinces. An example is the Jiulang.

- Plateau Grassland: mainly distributedin the high, cold pastures and steppes, with an annual mean temperaturebelow 2 degrees Celsius. Examples are the Maiwa and Luqu.

- White Yak: found in almost every region of district. An example isthe Tianzhu White Yak.

Work

Yaks are mainly used for packing in transport; they may travel 20-30 kmper day with a load of 130 lbs. on the high, cold, steep mountainous paths.This gives them the reputation of the "Ships of the Plateau".

Meat Production

They have a dressing percent of 45-54%. Yak meat, from either white orblack yaks, has a special flavor and if adequately processed and canned,it is much appreciated in China and as an export.

Milk Production

Milk is of economic importance in yak raising. Milk generally starts 10-15days after calving, which occurs in April and May, then continues for 5months until winter comes. Production is highest in July, when grass isabundant and nutritious, then declines as the grass dries off graduallybefore or in October.

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Although both Highland cattle and yaks belong to the same genus, bos or oxen and true cattle, their species differ. The Highland cattle belong to the bos taurus or true cattle species. According to the Animal Diversity Web, the yak belongs to the bos grunniens or oxen classification. Yaks can breed with cattle; however, the breeding produces fertile females and sterile male offspring.

1. History

- Highland cattle thrived in rough and rocky terrain.

  Yaks originated in the mountains of Tibet in Asia. Domestication of the yak occurred up to three thousand years ago. Wild yak live mainly in the mountains of China and Tibet. Highland cattle originally came from Scotland. The black smaller Highland cattle developed on the west coast islands of northern Scotland and the red larger variety in the Scottish Highlands.

2. Identification

- Highland cattle come in a variety of colors.

  A male yak may stand almost 6 feet tall at the shoulder and weigh over 2,000 pounds. Females usually weigh less than 700 pounds. Yaks have unique hemoglobin that allows them to live in altitudes as high as 18,000 feet above sea level. A yak has a large hump over their shoulder region and long blackish brown fur and upward curving horns. Yaks grow a thick short undercoat during the winter. Highland cattle possess long horns, and their long shaggy coat colors include red, black, yellow, dun, brindle and silver-white. Highland cattle generally measure about 3 to 3.5 feet at the shoulder; however, their weight is similar to yaks.

3. Significance

- People use yaks to carry heavy loads up steep mountains. Chinese consume yak milk, eat yak meat and export it. Yak fur and hide products include clothing, tents and blankets. The health, disease resistance, lean meat production, calm temperament and low-maintenance needs of highland cattle made them desirable livestock for cattle ranchers.

Distribution

- According to Oklahoma State University (OSU), almost 85 percent of all yaks live in China, predominantly in the mountains. Wide-range commercial breeding in other areas of the world remains limited due to the breed's adaptation to better survival at high altitudes. Breeding of the adaptable Highland cattle occurs in many countries, including the United States, Great Britain, Australia, Canada and Switzerland.

Future Survival

- Neither Highland cattle nor domesticated yak presently face danger of extinction. Both species fill economic needs, as livestock and yaks continue to work as pack animals. Survival risks for wild yaks include lost of habitat and uncontrolled hunting. Both species live 20 years or longer in captivity.

Read more: Difference Between Highland Cattle & Yak | eHow.com
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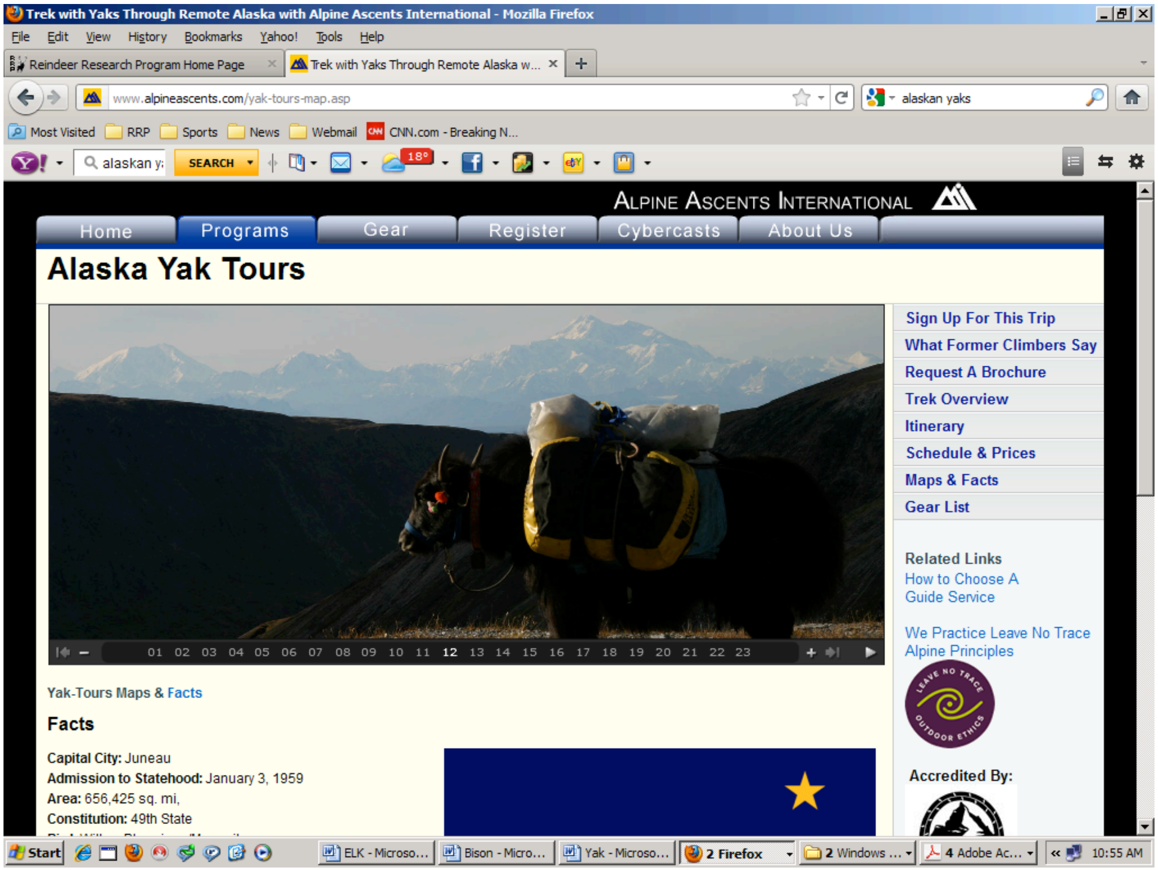

EASONS WHY TIBETAN YAKS ARE THE VERY BEST OF ALL LIVESTOCK ANIMALS FOR ALASKA

MADE FOR ALASKA

Yak are native to the high Himalayan plateau of Tibet where over thousands of years they have provided great diversity of use to a great culture of people. That these peoples not only survived, but thrived in an extremely harsh environment relates directly to their dependency and utilization of their great Yak. Yak have extreme cold-weather hardiness but also are low elevation tolerant. Alaska is ideally suited for their inherent natural attributes. Most importantly, in Alaska where so many elements work against a prudent business plan related to raising, producing and maintaining livestock, Yak actually thrive in our environment, consume less feed and are the most diversified of all livestock animals in relation to value added concepts.

GREAT FOR ALASKA'S YOUTH

Yaks are magnificent animals that are pleasant to watch or spend time with. They add a uniqueness to any pasture they are in. Yak are very intelligent, athletic and a joy to train. As such, they are ideally suited for agricultural programs for Alaska's youth to raise, train, enjoy and reap the benefit of producing a valuable commodity. Whether it be fiber, food, ridding/pack animal, starting their own herd, helping others to do the same or just the inherent value of having a responsibility that can be rewarding and fun in many ways.

BEST TASTING MEAT

Yak meat may well be the best tasting meat in the world. It has a sweet, juicy, delicious beef like taste that is gourmet in quality. Nine out of ten people in blind taste tests prefer the taste of Yak over bison, elk or high quality beef.

HEALTHIEST RED MEAT

Yak meat may well be the healthiest red meat in the world. Naturally very lean, but also high in Omega 3s and CLAs, low in saturated fats, cholesterol, triglycerides and very low in Palmitic acid compared to beef. Healthier than skinless chicken and fish. Yak meat is a red meat which helps combat cardiovascular diseases by keeping cholesterol in check and offers heart patients a new opportunity in fine dining. It also offers athletes a diet exceptionally rich in body building proteins, minerals, vitamins, and the right fats for building muscle and good health.

LESS EXPENSIVE TO RAISE AND MAINTAIN

Yak consume one percent of their body weight in forage per day compared to a beef animal which consumes three percent. What this means is that an average yak cow will consume 6 to 8 pounds of expensive Alaska hay per day when a beef cow will consume approximately 30 to 40 pounds.

HIGHER WEIGHT GAIN RATIO

Weight gain per pound of feed for yak is higher than that of beef which means you need less forage or expensive feed for higher weight gain ratio.

NATURALLY DISEASE RESISTANT FOR ALASKA

Yaks have a natural high resistance to diseases. Alaska's climate will help to continue this great trait. As Alaskans, we have an inherent responsibility of maintaining good health in our livestock by using preventive programs that will protect our wildlife populations. Yak naturally help to accomplish and sustain this mandatory requirement.

EASY KEEPERS

Yak are generally easy to keep in and require no more fencing that beef cows and do not require any special winter shelter. Calves will explore the green grass on the other side of the fence so precautions like an electric line or woven fence may be required to keep them from exploring new habitats. Naturally, when breeding age bulls are separated from the cows they must have special fencing to retain them.

BROWSERS – GRAZERS

Yak are browsers and grazers and as such, do well on a variety of Alaskan pastures. They love their grass but also do well on Alaska's sedges, willow and other deciduous brush which in certain pastures actually will help to clear land and keep it clear of unwanted growth.

AT HOME ON ALASKA'S TRAILS

With thousands of years use in the Himalayas as riding, trekking, pack and draught animals, Yaks truly offer a unique, functional and minimal impact addition to Alaska's back country. At home in the alpine, more sure footed than mules or horses, incredible strength combined with their natural docile behavior, it is no wonder that Yaks still represent the main source of access for supplies and support staff to the Mount Everest base camps. In Alaska, the year around recreational and tourism support potential for this great animal is unlimited.

NATURALLY GUARD AGAINST PREDATORS

Yaks have great natural herd and family instincts which makes them extra great livestock for Alaska. Woe be on the wolf, coyote or bear who challenges the yak herd. Like muskoxen, yak will herd up when a bear or a wolf comes by and you will not see the calves within the circle of protection. But unlike muskoxen, yak will actually advance on the predator and fight to their death to protect their family members or their young.

HIGH DIVERSITY OF UNIQUE IN DEMAND CHARACTERISTICS

For the consumer/investor looking for true diversity, yaks offer real profits right now in; gourmet meat production, in healthiest meat offerings for health conscious consumers and athletes, in luxurious and functional wool production for spinners and weavers, in premium leather, hides, skulls and hair for artists, craftsmen and furniture makers, for packing, trekking, riding and pulling animal disciplines, in visually enjoyable breeding stock for exotic animal raisers or crossbreeding for pioneering cattle raising to produce the highest quality red meat in the world, or exploring the great potential for sweet, rich milk, butter, and cheese, Yaks truly represent the best and most diversified livestock for Alaska.

If you want to actually get to know some Alaskan Yaks, schedule a visit to Robert and Barbara Fithian's Circle F Ranch in Lower Tonsina but be warned, once you go Yak you never go Back!

Cattle ranchers at the National Western Stock Show in Denver were doing double takes the other morning when they walked by the yak pens. The yaks, with their shaggy appearance and grunting sounds, look like Ice Age relatives of the massive beef cattle elsewhere in the stockyards. Yaks are about half the size of domestic cattle -- with the three-month-old calves no bigger than an adult Newfoundland dog.

Yaks are still quite exotic in the U.S. and Canada. But the fact they've been a presence at one of the world's largest livestock events for several years now says something about both the animals and their breeders -- who swear up and down that yak meat and yak wool are the next big thing. Perhaps, at some future point, even the new buffalo.

Self-Sufficient, Ecologically Sound

Native to Asia's Himalayan Mountains, most of the 9,000 or so domestic yaks in North America reportedly descend from zoo animals brought to Canada a century ago. The animals love high altitudes, cold weather and dry climates -- and have done very well in the Rockies.

Some yak ranchers say their animals eat like goats, consuming weeds and shrubs most beef cattle and horses avoid. "You can put four yak cows on the same acreage as one commercial beef cow," says breeder Bob Hasse, who's also on the International Yak Association's board of directors. While there is some difference of opinion over whether it's four cows or two cows per acre, there are other good reasons to raise yaks. "They're much lighter weight, so they're much easier on the environment," says Hasse.

"They'll thrive where cattle would starve. They also eat and drink about a third of what beef cattle do," says Joe Phillips, who started raising yaks about two years ago in Colorado's High Country. This time of year, he says, "you do have to feed them some hay, but they can handle the cold, they can handle the predators, it's not an issue. So I'm hoping to see more of them in the county and surrounding high-altitude areas."

Expensive Meat, Valuable Wool

Yak tastes like very lean beef, and their meat is low in fat. They take twice as long as cattle to mature, however. And yak is still considered an exotic meat like bison or elk. Because of that classification, Hasse says, any yaks prepared for public consumption have to be processed in a U.S. Department of Agriculture facility under a volunteer program -- where the yak producer pays for both the inspections and the inspectors' time.

And those costs add up for the yak rancher. "You can get grass-fed beef [processed] at a private facility for 50 to 75 cents a pound," he says. "The price of beef that goes into a store from a monster facility . . . runs between 25 and 35 cents a pound. Our costs [for Yak] run between a buck to a buck-and-a-half [per pound] for processing."

All those processing expenses mean that, even if you can find yak meat at your local market, it'll probably cost you two to three times the cost of a similar beef cut.

Good Reviews From a Weaver

Yaks are also valued for their wool. The animals have a coarse, dense, protective outer coat, but their inner "down" coat has a texture that compares favorably to cashmere. "The down is competitive to -- in the same realm as -- camel hair [and] alpaca," says Heather Morrissey, a weaver and hosiery producer from Ontario. She's currently working with yak wool fibers from Mongolia but is "looking at some of the domestic wool, both in the U.S. and Canada."

And while yak wool is still a niche market, Morrissey says it's where she wants to be. "I think it's got potential, probably in the next decade, to seriously bump it up a notch or two, looking at a commercial level," she says. "But right now I think it's at its infancy. It's going to be at a cottage-level for a bit. But I think . . . you have to structure it in such a way that it's similar to the way the other wool businesses are, so that you can take it to market."

"We're seriously in the pioneering stage," says Hasse. "We're learning what we have. Every time we learn something new, it's positive. With less than 10,000 animals in the country, we're scratching the surface. But the more people get to know [yaks], when they take the time, [the more] they're interested in the economics.