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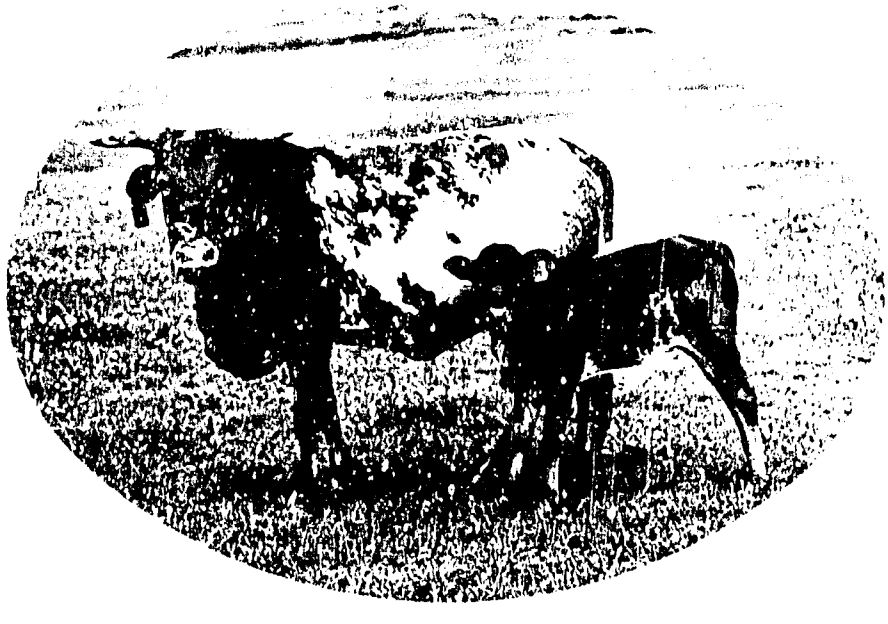
ILCA Monograph No 6

A Review of Reproductive Performance of Female *Bos Indicus* (Zebu) Cattle

by E Mukasa-Mugerwa



August 1989

International Livestock Centre for Africa

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August 1989

International Livestock Centre for Africa
P.O.Box 5689, Addis Ababa, Ethiopia

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SUMMARY

This monograph summarises knowledge of the reproductive biology of cows, with emphasis on *Bos indicus* types. After a brief introduction to the reproductive anatomy and endocrinology of the cow, subsequent chapters describe changes which occur at puberty, during the oestrous cycle, and at pregnancy; measures of reproductive performance; causes of infertility, and how these can be diagnosed and their effects minimised; the role of nutrition in cattle reproduction; lactational anoestrus and the effect of weaning; and herd health programmes. Data from Africa, Asia, America and Australia are presented. Where data from zebu cattle were not available, points are illustrated or emphasised using data on *Bos taurus* cattle, or other species.

This monograph is intended for field workers in agriculture and livestock production and health, particularly in Africa. However, it gives enough detail to be useful also to higher degree students and researchers.

KEY WORDS

/Zebu cattle//*Bos indicus*//Breeding//Reproduction//Animal physiology/ /cows/ – /Endocrinology//Reproductive performance// Reproductive disorders//Infertility//Animal nutrition//Animal health//Oestrous cycle//Weaning/

RESUME

La présente monographie fait le point des connaissances en ce qui concerne la biologie de la reproduction chez la vache, notamment de type Bos indicus. *Après une brève introduction consacrée à l'appareil reproducteur et à l'endocrinologie, cette étude décrit les changements survenant à la puberté, au cours du cycle oestral et de la gestation; la mesure des performances de reproduction; les causes, le diagnostic et les solutions possibles de l'infertilité; le rôle de la nutrition dans la reproduction chez les bovins; l'anoestrus de lactation et l'effet du sevrage; et des programmes sanitaires destinés à des troupeaux bovins. Les analyses sont basées sur des données rassemblées en Afrique, en Asie, en Amérique et en Australie. Celles-ci se rapportent essentiellement au zébu, mais parfois à* Bos taurus *ou à d'autres espèces bovines lorsqu'on ne dispose pas d'information sur le zébu.*

D'abord destinée aux agents du développement agricole et des services de l'élevage en Afrique notamment, cette monographie est cependant suffisamment bien documentée pour intéresser également les étudiants et les chercheurs travaillant dans les domaines de l'agriculture, de la production et de la santé animales ou dans des disciplines connexes.

MOTS-CLES

/*Bovin zébu*/ Bos indicus/ *reproduction*/*physiologie animale*/*vaches*/ – /*endocrinologie*/*performances de reproduction*/ *troubles de la reproduction*/ /*infertilité*/ *nutrition animale*/*santé animale*/*cycle oestral*/*sevrage*/

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FOREWORD

This monograph gives an account of current information on factors affecting reproduction in female zebu cattle. It includes a summary of basic reproductive anatomy and endocrinology, followed by in-depth reviews of the effects of nutrition, genetics, herd management and disease on overall reproductive performance in this type of cattle.

In the tropical areas of the world, zebu *(Bos indicus)* cattle are much more numerous and important than the European breeds of the *Bos taurus* species. Zebu cattle are well adapted to the tropical conditions of high temperature and humidity, parasites and low quality forage, but their reproduction and fertility are usually rather low. They are characterised by late puberty in the female and long calving intervals. However, there are zebu herds in some tropical regions that have very acceptable levels of reproduction. We may raise the question, if adequate reproductive levels (80 to 85% pregnancy) can be achieved with zebu breeds in some tropical areas, why cannot the principles involved in achieving these levels also be applied in other areas to provide needed protein for the human population?

The information in this volume should be helpful to teachers, researchers, livestock extension workers, cattle producers, agricultural leaders, political leaders and planners in their efforts to improve the reproduction rate in zebu cattle in many areas.

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E. Mukasa-Mugerwa

1. INTRODUCTION

ILCA's studies over the past 15 years have shown a high degree of complementarity between livestock and crop production, and indicate that improving livestock production can stimulate crop production and increase the acreage cultivated by small-scale farmers.

Smallholder mixed farming systems predominate in the tropics. Livestock play several roles in these systems: they use resources that would otherwise go to waste, such as crop residues and fallow land; they provide meat and milk for consumption or sale; and their manure can be used as fuel, fertilizer and, sometimes, cement. Cash generated by their sale can be used to purchase farm inputs such as seed, fertilizer and implements. Larger animals, e.g. cattle, provide draught power for cultivation, transport and crop threshing. Exports of live animals and animal products and byproducts make substantial contributions to the foreign exchange earnings of many countries.

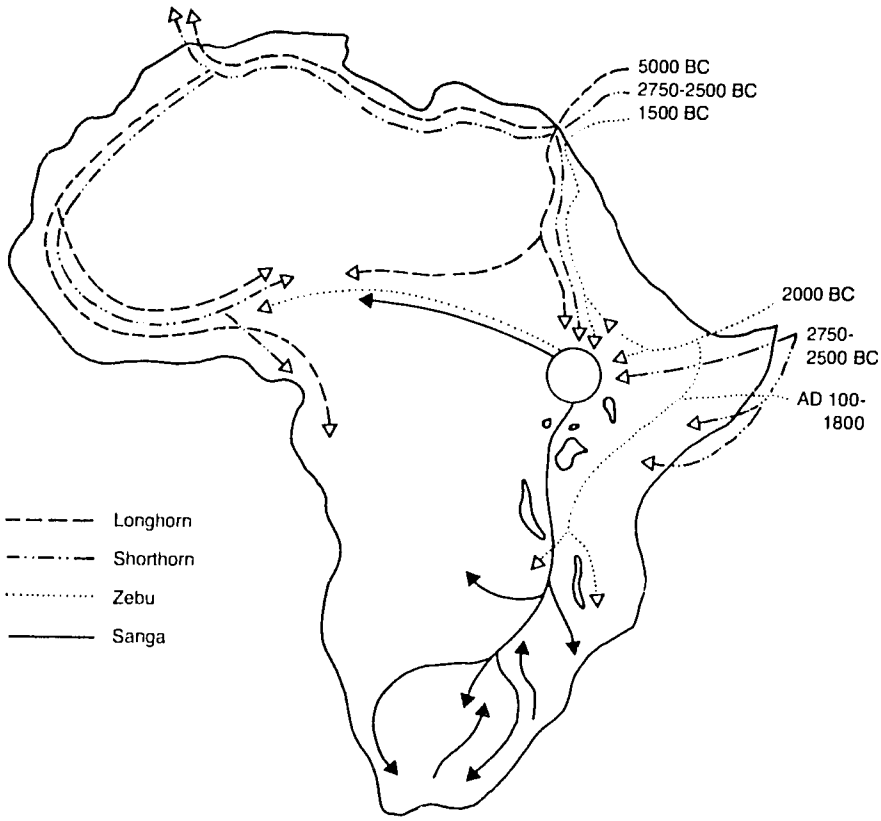
Despite their economic importance, the productivity of cattle in the tropics is low. The reasons for this include the low genetic potential of indigenous breeds, poor husbandry and a variety of environmental factors, including high ambient temperature and humidity, seasonal shortages of feed and water, diseases and parasites.

Some breeds of cattle, usually *Bos indicus* or those with a large proportion of *Bos indicus* blood, are well adapted to the harsh environmental conditions of the tropics. Essential adaptive traits include resistance to, or tolerance of, pests and diseases; tolerance of intense sunshine, heat and humidity; and ability to utilise high-fibre forages (Koger, 1963). However, the potential for meat and milk production of *Bos indicus* cattle is commonly low: they mature late and produce little milk, which they often let down only in the presence of their calves. One way to increase the productivity of *Bos indicus* cattle is to cross them with temperate *Bos taurus* breeds, such as the Holstein-Friesian and the Hereford.

1.1 *Bos indicus* cattle in Africa and worldwide

The African cattle population derives from three major introductions from Asia (Epstein, 1957; Faulkner and Epstein, 1957; Williamson and Payne, 1977; Oliver, 1983). The first cattle introduced into Africa, the humpless Hamitic longhorn (*Bos taurus longifrons*), arrived about 5000 BC. They were followed by the humpless shorthorn (*Bos taurus brachyceros*) about 2500 years later and the humped zebu (*Bos indicus*) in about 1500 BC. Most cattle followed the Nile Valley through Egypt or came through the Horn of Africa (Figure 1). Further migrations resulted in a heavy concentration of cattle in the highlands of Ethiopia and Kenya, regarded today as one of the original sites of Africa's indigenous cattle. Interbreeding among these three types resulted in the Sanga, a so-called intermediate type because of the length of its horns and the location of its hump (Mason and Maule, 1960).

Figure 1. *Possible migration routes of domestic cattle in Africa*



Source: Oliver (1983).

The name Sanga was originally applied to the giant-horned Galla cattle: in the Oromo (formerly Galla) language of Ethiopia, Sanga means ox.

Native breeds of Africa include the humpless N'Dama, Kuri and Dwarf Shorthorn; the humped Azaouak, Sokoto, Senegal Fulani, White Fulani, Red Bororo, Abyssinian, Boran, Small East African Zebu and Angoni; and intermediate types such as the Bambara, Ankole, Danakil, Barotse, Tuli, Mashona, Nguni, Basuto and Africander.

Zebu[1] cattle are common in other parts of the world. There are about 30 zebu breeds in the Indian region alone, including Gir (Gyr), Haryana, Kankrej (Guzerat), Ongole (Nellore), Red Sindhi, Sahiwal and Tharparkar.

The American Brahman was developed by crossing native American cattle with Asian zebu cattle (Phillips, 1963). Brahmans are now used widely for beef production in the tropics (Koger et al, 1973). Large numbers of Asian cattle were introduced into Brazil between 1813 and 1964, and subsequently spread to other countries in the region. The Brahman breed has been maintained in its original form, improved, and used in the development of new breeds, such as the InduBrazil (Gir × Guzerat), Canchin, Jamaica Hope, Sibovey, Santa Gertrudis, Brangus, Beefmaster and Simbrah. The Nellore (Ongole), Gir and Guzerat (Kankrej) breeds are also present in substantial numbers in South America.

Australia's large *Bos indicus* population originates mainly from cattle introduced from India, Pakistan, South Africa and America. The Africander breed was used in the development of the Belmont Red, the Brahman

[1] *Bos indicus* is used interchangeably with the term "zebu", which originates from the Tibetan word Zen or Zeba, which means "the hump of the camel".

breed for the Droughtmaster, and the Australian Milking Zebu was developed partly from the Sahiwal. Further details can be found in Mason (1951), Joshi and Phillips (1953), Mason and Maule (1960), Epstein (1971), and McDowell (1972).

1.2 Productivity and reproduction

The productivity of cattle largely depends on their reproductive performance. Cows that rarely deliver a live calf are not worth keeping. Poor reproductive performance is caused by:

- failure of the cow to become pregnant, primarily due to anoestrus (prepubertal or postpartum);
- failure of the cow to maintain the pregnancy; and
- calf losses.

This monograph summarises knowledge of the reproductive biology of cows, with emphasis on *Bos indicus* types. After a brief introduction to the reproductive anatomy and endocrinology of the cow, subsequent chapters describe changes which occur at puberty, during the oestrous cycle, and at pregnancy; measures of reproductive performance; causes of infertility, and how these can be diagnosed and their effects minimised; the role of nutrition in cattle reproduction; lactational anoestrus and the effect of weaning; and herd health programmes. Data from Africa, Asia, America and Australia are presented. Where data from zebu cattle were not available, points are illustrated or emphasised using data on *Bos taurus* cattle, or other species.

This monograph is intended for field workers in agriculture and livestock production and health, particularly in Africa, who may not have access to current publications on this subject. However, it gives enough detail to be useful also to higher degree students and researchers. It is hoped that this review will stimulate more research, especially in Africa.

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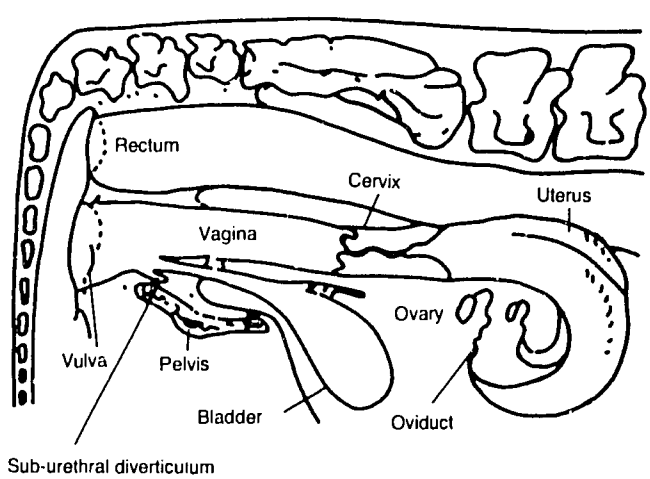
2. ANATOMY AND ENDOCRINOLOGY OF COW REPRODUCTION

2.1 Anatomy

The genital tract of non-pregnant cows normally lies in the pelvic cavity and consists of the vulva, vagina, cervix, uterus, Fallopian tubes (oviducts), ovaries and their supporting structures (Figure 2). Most of the reproductive structures can be palpated through the rectum; this is the basis of routine fertility work described in subsequent sections of this monograph. In general the reproductive tract of *Bos indicus* cattle is smaller than that of taurine cattle. The reproductive tract is supplied by blood from the utero-ovarian and uterine arteries, of which the middle uterine artery is the largest.

Figure 2. *The reproductive tract of the cow (lateral view) showing its position inside the pelvic and abdominal cavities*



Source: Peters and Lamming (1987).

The uterus is a muscular organ consisting of a body, about 4 to 5 cm long, and two uterine horns (cornua), each 15 to 25 cm in length and 1 to 3 cm in diameter. The uterus is suspended by the broad ligament in a coiled or curled manner. Its size varies with breed, age, parity, pregnancy and disease

The cervix is a sphincter-like structure with a thick wall and a narrow lumen. This lumen is tightly closed, except during oestrus and at parturition, and the cervix forms a barrier between the uterus and the outside environment. The length of the cervix varies from 1.5 cm in heifers to 8 cm

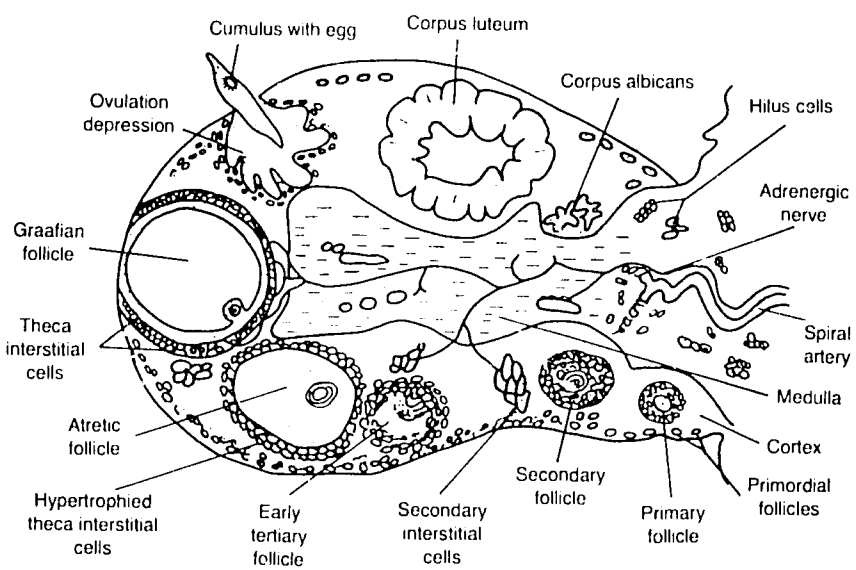
in multiparous cows of larger breeds. Interlocking ridges and complex folding of the lumen mucosa can hamper insertion of a pipette or tube for intra-uterine insemination or infusions.

The vagina extends backwards from the cervix and opens into the vulva. Its length varies with breed and stage of pregnancy. The vaginal epithelial cells near the cervix secrete mucus, especially around the time of oestrus.

The ovaries are oval-shaped structures, 1 to 4 cm long and 1 to 3 cm in diameter; their size depends on the stage of the reproductive cycle. They are linked to the uterus by the Fallopian tubes which open anteriorly into the fimbriae—funnel-shaped structures close to, but not attached to the ovaries. The fimbriae guide unfertilised eggs from the ovary into the Fallopian tubes.

Figure 3 is a schematic representation of the mammalian ovary. The ovary has two major functions: gametogenesis (the production of female gametes) and steroidogenesis (the production of steroid hormones, which play vital roles in the reproductive cycle).

Figure 3. *The morphology and architecture of a mammalian ovary during the reproductive cycle*



Source: Erickson et al (1985).

The ovary of a new-born heifer may contain up to 100,000 primordial follicles (Erickson, 1966). However, only a few of these mature and release an ovum. From birth to shortly before puberty the primordial follicles are in a state of arrested development (dictyotene; the resting stage). Shortly before puberty, many primordial follicles start to grow and develop in response to hormone (gonadotrophin) stimulation. The presence of developing follicles indicates active gametogenesis and steroidogenesis. During each oestrous cycle, several follicles may develop to the Graafian stage, but usually only one reaches full maturity and ruptures to release the ripe ovum (ovulation): the others become atretic (also known as degenerating, luteinising or anovulatory follicles) (McDonald, 1980).

Ovulation involves changes in steroid, gonadotrophin and prostaglandin secretions along with alterations in ovarian neuromusculature, in particular the breakdown of the follicular wall, escape of the ovum and release of

follicular fluid. The ovulation fossa formed after ovulation fills with blood to become the corpus haemorrhagicum and eventually the corpus luteum (yellow body), which protrudes from the surface of the ovary. For details on the histology of the corpus luteum, see, for example, Corner (1915); McNutt (1924); Foley and Greenstein (1958); Gier and Marion (1961); Donaldson and Hansel (1965); Parry et al (1980); Alila and Hansel (1984); and Braden et al (1988). The corpus luteum is part of the endocrine system.

2.2 Endocrinology of reproduction

The development of radio-immunoassay (RIA), competitive protein binding (CPB) and enzyme-linked immunosorbent assay (ELISA) methods since the 1960s has allowed rapid, accurate and sensitive measurement of the concentration of several pituitary, ovarian and adrenal hormones in blood, tissue, milk and urine. Ovarian tissue can now be studied in vitro. Cells can be broken down and the secretion and use of hormones by their organelles examined. The interrelations among hormones at various stages of the reproductive cycle in the female cow are therefore better understood, as are the physiological control mechanisms that govern reproductive function (Entwistle, 1983).

The endocrine system comprises a series of ductless glands, each of which secretes one or several hormones that integrate body functions. Hormones are secreted directly into the blood and act on tissues elsewhere in the body.

The reproductive cycle of the cow is mainly coordinated by hormones produced by the hypothalamus, pituitary and ovary. Gonadotrophic releasing hormone (GnRH), secreted by the hypothalamus, stimulates the anterior pituitary to secrete two gonadotrophic hormones – follicle stimulating hormone (FSH) and luteinising hormone (LH). Both of these hormones control ovarian function: FSH initiates maturation of follicles, and LH induces ovulation and luteinisation of granulosa and thecal cells. The major hormones produced by the ovaries are oestrogens (primarily oestradiol-17β), which are produced by the follicles, and progesterone, secreted by the corpus luteum. Oestrogens play important roles in oestrus manifestation, and progesterone in maintenance of pregnancy. Both regulate the reproductive cycle through a series of feedback mechanisms acting on the hypothalamus and pituitary glands. In addition to these hormones, prostaglandins, which are produced by several tissues, including the uterus, also control the cow reproductive cycle in various ways. Details of the functions of these hormones at puberty, during normal oestrous cycles, during pregnancy, and in the postpartum period are given in the following sections. Other hormones, produced by the thyroid, parathyroid and adrenal glands, the placenta and the pancreas are also important in regulating reproduction.

For information on hormone action at the cellular level, see, for example, Eisenfeld (1972), Calandra et al (1974), Kato et al (1974), Catt et al (1975), Saxena (1976), Greenstein (1978), Cermak et al (1983), Spellberg et al (1983), Saxena et al (1984), McCracken and Okulicz (1984), Smith et al (1985) and Bergh et al (1985).

There are differences in the hypothalamic, pituitary and ovarian relationships in zebu and taurine cattle (Rollinson, 1955; Plasse et al, 1970; Griffin and Randel, 1978; Randel, 1976, 1984; Rhodes et al, 1979). These differences probably account for differences in fertility between the two species even when similarly fed and managed (Rhodes et al, 1982).

This section highlights the endocrinology of reproduction in *Bos indicus* cattle. Data from taurine cattle and other species are used for emphasis and where information for zebu cattle is not readily available.

2.2.1 Endocrine changes in the prepubertal heifer

Little information is available on the hormonal control of puberty in the zebu. Early studies tended to compare the endocrine patterns in heifers with those of more mature animals. It was originally thought that the pituitary of prepubertal animals was incapable of elaborating sufficient gonadotrophic hormones to stimulate the ovaries. This was based on observations, such as those by Macfarlane and Worrall (1970) among Boran zebus, that administering gonadotrophins stimulated follicular growth and ovulation. However, follicle growth starts soon after birth (Desjardins and Hafs, 1968), as does the release of gonadotrophins, FSH and LH (Peters and Ball, 1987). The ovaries of 2-month old calves can respond to gonadotrophin therapy (Onuma et al, 1970) and calf follicles can secrete oestrogens. Prepubertal ovaries also respond when transplanted to mature animals (Russell and Douglas, 1945) and injecting oestradiol results in LH release in calves as young as 3 months old (Schillo et al, 1983). The possible causes of sexual maturation at puberty appear to be an increase in pituitary hormones output culminating in increased size and activity of the ovaries (Hunter, 1980), and maturation of the hypothalamo-pituitary axis, resulting in secretion of gonadotrophins (Ramirez, 1973).

2.2.1.1 Luteinising hormone

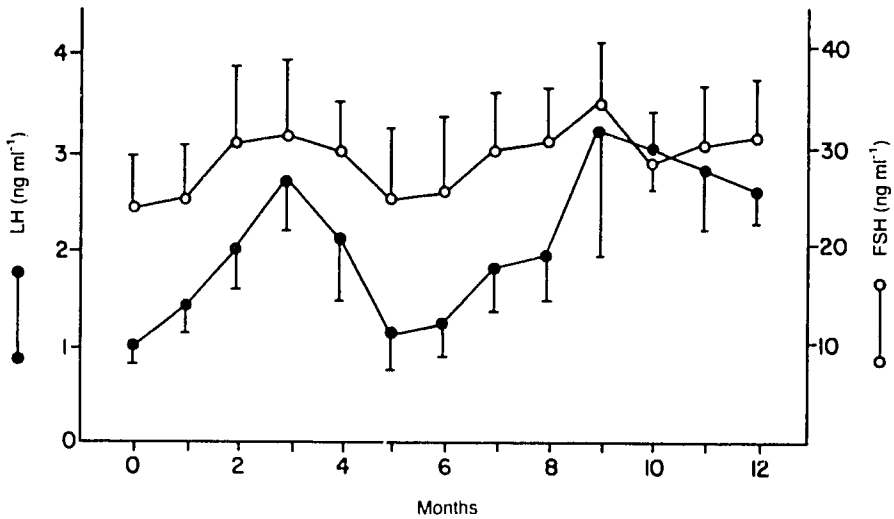
LH levels fluctuate before puberty (Desjardin and Hafs, 1968) but tend to increase as puberty approaches (Swanson et al, 1972). By taking samples more frequently from Angus heifers, Gonzalez-Padilla et al (1975a) confirmed that prepubertal heifers do not lack LH as such, but there is no cyclic pattern to its release. Two LH peaks were observed prior to puberty, the first (priming) peak at 9 to 11 days before first oestrus. This diphasic profile was also observed among Brown Swiss heifers by Schams et al (1981). In heifers attaining puberty at 10 months old, LH and FSH levels increased from birth to 3 months, declined to a nadir at 5–6 months and then increased to a second peak at about 9 months (Figure 4).

LH secretion in prepubertal heifers is probably suppressed through an inhibitory feedback (gonadostat) effect (Anderson et al, 1985). As noted above, components of the endocrine system can apparently function soon after birth (Ramirez and McCann, 1963). LH is secreted from the pituitary gland and stimulates ovarian follicles to produce oestradiol-17β. However, the hypothalamus-pituitary axis is highly sensitive to the negative feedback effect of oestradiol, and further LH release is inhibited. Ovariectomy of immature rats significantly increases the concentration of plasma LH (Ramirez and McCann, 1963; Caligaris et al, 1972) and FSH (Kragt and Masken, 1972). The same is true in the calf (Odell et al, 1970). The sensitivity of the hypothalamus-pituitary axis to oestradiol must thus decrease prior to puberty in the heifer (Schillo et al, 1982). This allows LH to stimulate follicular growth and leads to increased oestrogen production (Foster and Ryan, 1981) and ovulation.

2.2.1.2 Oestradiol and progesterone

There are few reports on the plasma concentration of oestradiol-17β in prepubertal heifers. Glencross (1984), using a sensitive and fully validated

Figure 4. *Plasma LH and FSH concentrations (± SEM) of female calves from birth to 12 months of age*

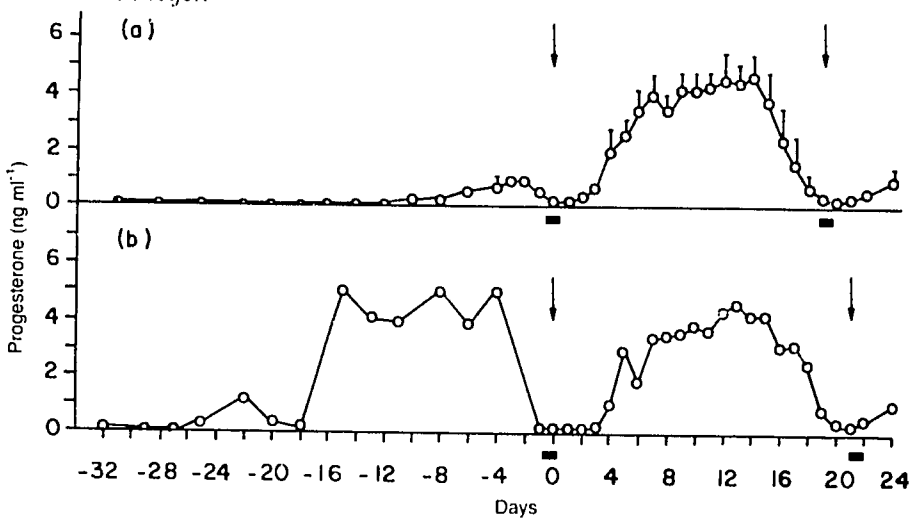


Source: Adapted from Schams et al (1981).

radio-immunoassay, found that the plasma oestradiol-17β levels of four British-Friesian heifers varied randomly within the range 1 to 4 ng/litre between 59 and 15 days before puberty. About 8 days prior to puberty, oestradiol-17β levels increased significantly ($P < 0.02$) to a mean of 6.3 ± 1.3 ng/litre, comparable to the normal preovulatory peak in post-pubertal heifers. It was not clear, however, if this induced an LH surge and ovulation. Progesterone levels subsequently rose ($P < 0.001$) to a peak of 1.0 ± 0.1 μg/litre on the fourth day, indicating some luteinisation. After the return of the progesterone to basal levels, oestradiol-17β again rose significantly ($P < 0.001$) to a second peak of 9.0 ± 1.0 ng/litre on the day of first oestrus. Following this second peak, concentration of progesterone in the plasma remained high and pregnancy was confirmed in three of the heifers. The second peak in oestradiol-17β concentration had therefore been followed by ovulation. A third oestradiol-17β peak ($P < 0.02$) of 4.3 ± 0.8 ng/litre occurred 4 days later, when progesterone levels were rising sharply due to the formation of a corpus luteum. The changes in oestradiol-17β and progesterone on or after the day of first oestrus were similar to those observed in post-pubertal heifers (Glencross and Pope, 1981; Glencross et al, 1981) and mature cows (Echternkamp and Hansel, 1973; Glencross et al, 1973, Smith et al, 1975).

Studies among *Bos taurus* heifers showed that progesterone concentration is low through most of the prepubertal period with two rises before puberty (Gonzalez-Padilla et al, 1975a). The first occurred between 18 and 11 days before the LH peak and was thought to be of adrenal origin. The second, from 9 days before until the day of the LH peak, was assumed to be of ovarian origin. Schams et al (1981) also observed an increase in progesterone concentration for 8–12 days before first oestrus in four Brown Swiss heifers that attained puberty at about 10 months old (Figure 5). A fifth heifer, which showed first oestrus at 14 months, exhibited a progesterone secretion pattern resembling that of a normal corpus luteum during the 18 days before first oestrus. Prior to this rise, levels were elevated for 8 days,

Figure 5. *Mean (± SEM) plasma progesterone levels before and after the first oestrus in heifers*



a = 4 heifers attaining puberty at 303 ± 11 days of age
b = 1 heifer attaining puberty at 414 days of age
The arrows indicate the time of the preovulatory LH surges
■ indicates the time of oestrus

Source: Schams et al (1981).

but only slightly (Figure 5). Similar elevations in progesterone concentration were reported by Berardinelli et al (1979) who attributed them to small luteal tissues, deeply embedded in the ovary, which could not be palpated. This agrees with Ojeda et al (1980), who stated that, in general, there is no compelling evidence for a role of adrenal sex steroids in the onset of puberty. These initial rises in progesterone may establish a phasic pattern to LH release and/or sensitise the ovaries to LH (Berardinelli et al, 1979) as in some postpartum cows.

The above observations have led to attempts to stimulate puberty. Most efforts have tried to simulate the transient rise in progesterone prior to first oestrus using implants or daily injections of progesterone combined with oestrogen or pregnant mare serum gonadotrophin (Gonzalez-Padilla et al, 1975b; Rajamahendran et al, 1982). Generally the treatments have been more successful in animals approaching puberty.

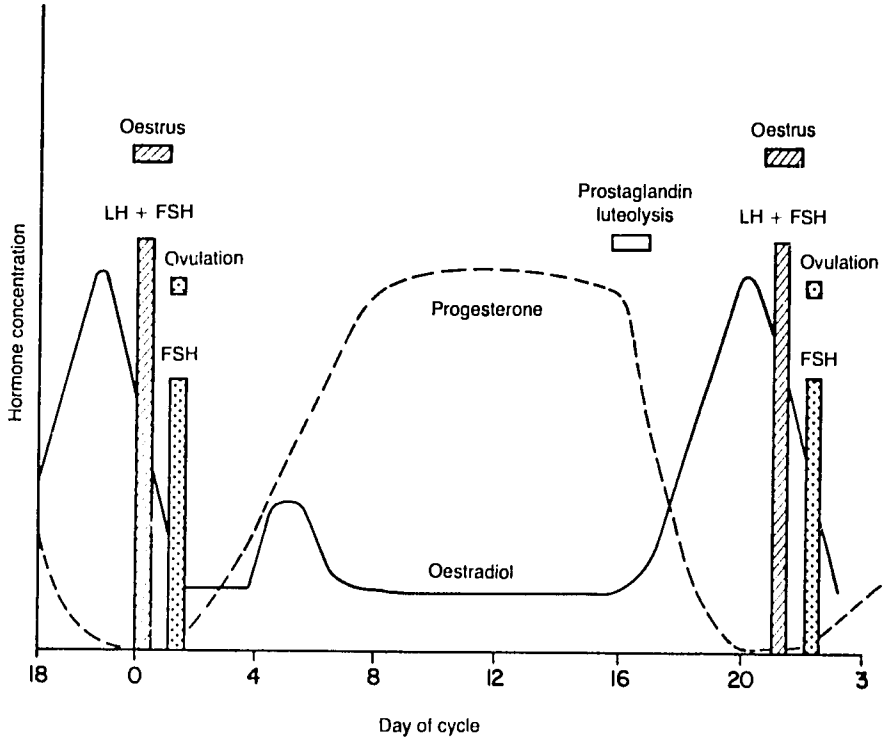
2.2.2 Endocrinology of the oestrous cycle

Figure 6 illustrates how the concentrations of the main reproductive hormones in the plasma change during the cow oestrous cycle. Hypothalamic GnRH induces the release of both LH and FSH from the pituitary (Kaltenbach et al, 1974; Schams et al, 1974). LH is released in pulses (Rahe et al, 1980, 1982) (Figure 7). Each LH pulse appears to be in response to a release of GnRH from the hypothalamus and LH secretion can be stimulated by GnRH injections. LH induces ovulation and luteinisation of the granulosa and theca cells. It also appears to be the principal luteotrophic factor in the cow (Peters and Lamming, 1983).

2.2.2.1 Luteinising hormone

LH concentration is low during most of the luteal phase of the oestrous cycle, with one pulse every 4 or more hours. It begins to rise a few

Figure 6. *Schematic representation of the changes in plasma hormone concentrations during the bovine oestrous cycle*



Day O = day cow first shows oestrus

Source. Peters and Lamming (1983).

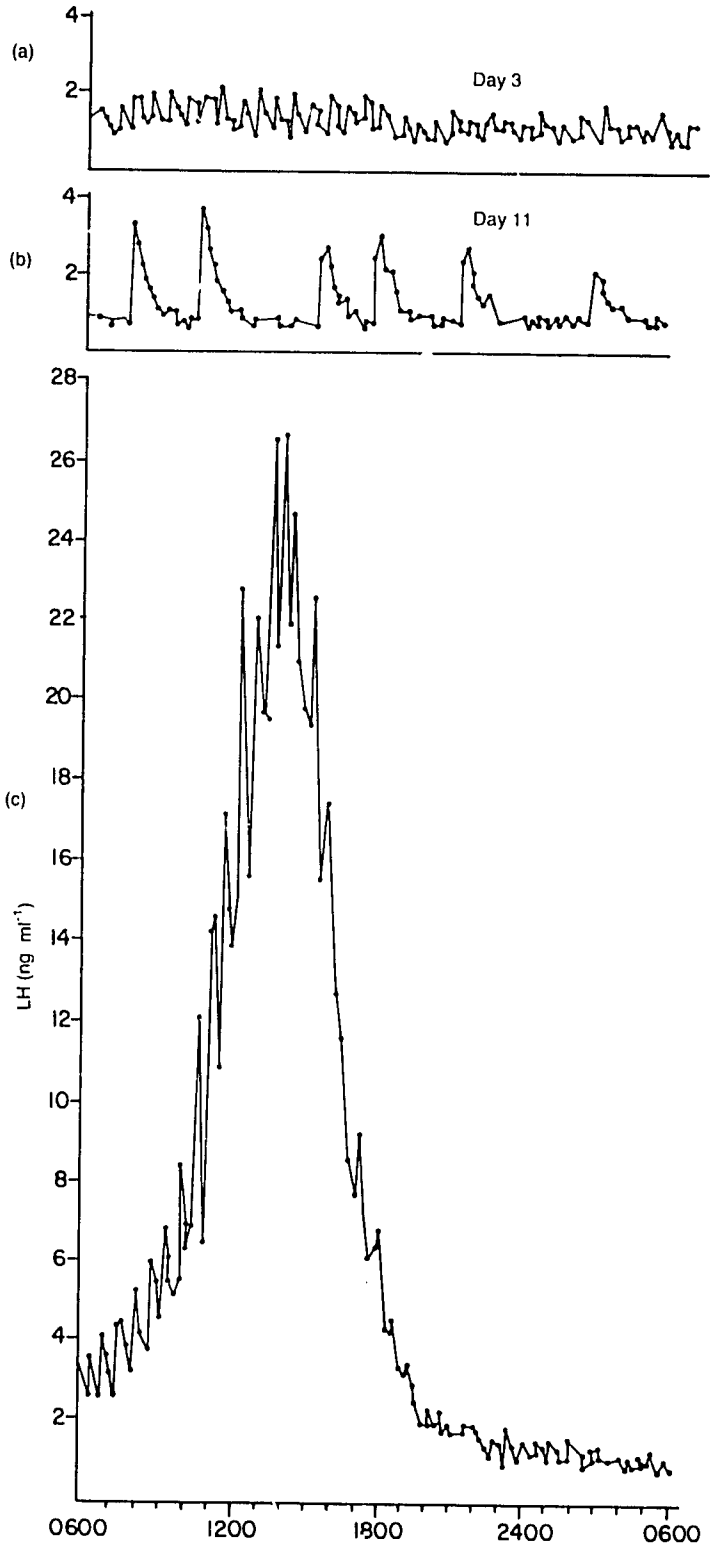
days prior to oestrus. Pulse frequency increases to one or more per hour; pulse amplitude, however, falls. The large preovulatory LH peak or surge that occurs near the beginning of oestrus is preceded by a rise in the concentration of oestradiol one or 2 days before oestrus.

Randel (1976) estimated the interval between oestrus onset and the LH surge to be 0.4 ± 3.4 hours in Brahman cows, 6.8 ± 2.1 hours in Brahman × Hereford cows and 5.3 ± 1.3 hours in pure Herefords. Randel and Moseley (1977) recorded intervals of 2.0 ± 1.3 in Brahman cows, 3.0 ± 1.0 in Brahman × Hereford cows and 6.5 ± 1.8 hours in Hereford cows. The preovulatory LH surge therefore seems to occur sooner after the onset of behavioural oestrus in zebu than taurine cows or their crosses. In addition, Randel (1976) estimated the interval between the LH surge and ovulation to be 18.5 ± 3.1 hours in Brahman cows, 22.2 ± 2.6 hours in Brahman × Hereford cows and 23.3 ± 2.1 hours in Hereford cows. Zebu cows thus appear to ovulate sooner after the LH surge than *Bos taurus* cows.

2.2.2.2 Oestradiol

Oestradiol-17β is the principal biologically active oestrogen. Randel (1980) measured total serum oestrogen (TSO) from 72 hours before oestrus until 24 hours after oestrus in Brahman, Brahman × Hereford and Hereford heifers. TSO did not differ significantly between breeds prior to oestrus.

Figure 7. *Pattern of plasma LH concentration on day 3 and 11 and the preovulatory LH surge on day 19 in the cow*



Source: Rahe et al (1982).

The highest pro-oestrous TSO level occurred 24 hours before oestrus in Brahmans, 8 hours before oestrus in Herefords and 16 hours before oestrus in the crossbreds. The pattern was similar for the lowest levels after oestrus: 24 hours after oestrus TSO levels were lower in Brahmans than the other two genotypes ($P < 0.05$) and these lower values coincided with ovulation. This finding agreed with data showing that Brahman cows tend to ovulate within 24 hours of the onset of heat, earlier than taurine cattle (Plasse et al, 1970; Randel, 1976). Randel's (1980) data also indicate that the oestradiol surge has two peaks. Echternkamp and Hansel (1973) proposed that the pre-oestrus rise in oestrogen mediates the LH release from the bovine pituitary, which in turn might stimulate the second oestradiol rise.

Glencross and Pope (1981), working with taurine cattle, found that oestradiol-17β levels are low in peripheral plasma for most of the oestrous cycle and rise as the concentration of progesterone begins to fall, reaching a peak 3 to 4 days later. Probably the drop in progesterone concentration following luteal regression allows the preovulatory follicle to increase its secretion of oestradiol-17β (Karsh et al, 1978). In the Holstein heifers used by Glencross and Pope (1981), plasma oestradiol-17β concentration was low at the start of luteal regression (2.2 $\pm$ 0.5 pg/ml), increased to 3.8 $\pm$ 0.6 pg/ml the next day and reached 6.6 $\pm$ 0.9 pg/ml when the concentration of progesterone in the blood had fallen to a minimum. The highest concentration of oestradiol-17β (10.1 pg/ml) was recorded one or 2 days after complete luteolysis. A similar trend was reported by Wettemann et al (1972).

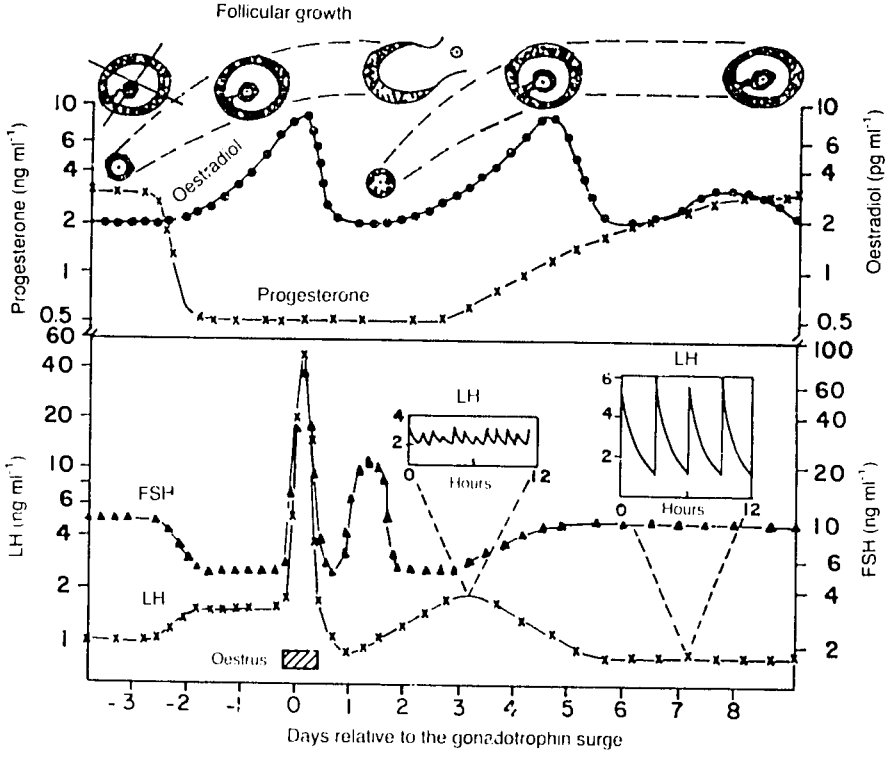
Glencross et al (1973), Smith et al (1975), Glencross and Pope (1981) and Hansel and Convey (1983) observed a second, postovulatory, peak in oestradiol 5 to 7 days after oestrus (Figure 8). The last authors observed this peak in non-pregnant cattle and those inseminated but failing to conceive. It appeared to be related to the presence of a large follicle. Its physiological significance is not clear but the follicle is not destined to ovulate (Peters and Ball, 1987).

2.2.2.3 Progesterone

Mukasa-Mugerwa et al (1989), using the ELISA method, found that the concentration of progesterone in the plasma of Ethiopian highland zebu cattle was less than 1.0 ng/ml from 2 days before oestrus to 3 days after oestrus. Llewelyn et al (1987) referred to this as the "basal progesterone" period. Progesterone concentration gradually increased from 4 days after oestrus (the "rising progesterone or early luteal" period), as the corpus luteum became functional. It reached a maximum of 8.0 to 10.0 ng/ml at 11 to 15 days after oestrus (the "plateau progesterone" period) and then declined (the "falling progesterone" period) to basal levels before the next oestrus and ovulation (Figure 9). A similar pattern in progesterone concentration was reported by Adeyemo and Heath (1980) in White Fulani cattle, Eduvie and Dawuda (1986) in Bunaji cattle, Coetzer et al (1978a) in Africander cattle, Vaca et al (1983) in InduBrazil cattle, Llewelyn et al (1987) in Boran cattle, Randel (1980) in Brahman cattle and their taurine crosses and Hansel (1981) in Holstein heifers.

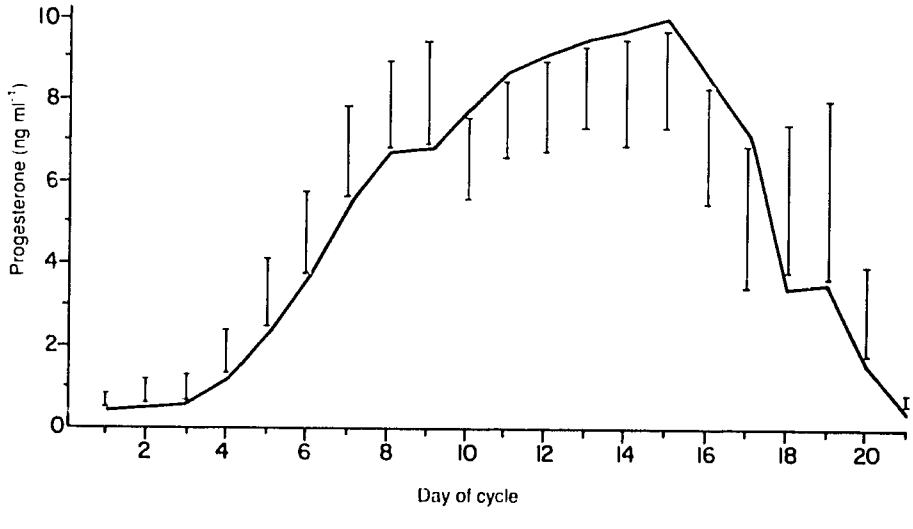
Coetzer et al (1978a) observed a drop in the concentration of progesterone in the blood of zebu cows about 13 days after oestrus. Similar observations were made by Erb et al (1971) and Schams et al (1977) in taurine cows. Coetzer et al (1978a) associated the decrease with mid-cycle follicle growth and development. They also found a small, but consistent, peak in progesterone concentration, 18–25 hours after the

Figure 8. *Follicular growth and endocrine changes from luteal regression to the resumption of luteal function*



Source: Hansel and Convey (1983).

Figure 9. *Mean (± SD) plasma progesterone levels during the oestrous cycle of Ethiopian zebu cows*



Source: Mukasa-Mugerwa et al (1989).

preovulatory LH surge, the time of ovulation. If consistent, this could be used to determine more precisely the time of ovulation.

Randel (1980) noted that progesterone concentration was generally lower in Brahman and Brahman × Hereford crosses than in purebred Hereford heifers. Between-breed differences in progesterone concentration have sometimes been suspected to arise from differences in ovarian size (Adeyemo and Heath, 1980; Irvin et al, 1978; Segerson et al, 1984a). The exact relationship is, however, not clear. Randel (1984), for example, suggested that the lesser responsiveness of the ovaries of Brahman cows to gonadotrophic hormone during formation of a corpus luteum might also result in a smaller corpus luteum. Nevertheless, the corpora lutea of Brahman and Brahman × Hereford cows had similar total progesterone contents. The Brahman corpora lutea seemed to have compensated for the small size. In fact, the activity of 3β-hydroxysteroid dehydrogenase, the enzyme responsible for converting pregnenolone to progesterone, was greater in corpora lutea from Brahman cows.

2.2.2.4 Prostaglandins

Oestrus usually occurs 1 to 5 days after the corpus luteum starts to regress. The regression of the bovine corpus luteum is brought about by the action of prostaglandin $F_2\alpha$ ($PGF_2\alpha$) (Knickerbocker et al, 1988). Dobson and Kamonpatana (1986) suggested that the variation in this interval is due partly to differences in the time ovulatory follicles take to develop and mature. Views on the growth, distribution and selection of follicles in the ovary differ. Choudary et al (1968), Donaldson and Hansel (1965) and Marion and Gier (1971) suggested that follicular growth is continuous and independent of the phases of the oestrous cycle. Matton et al (1981) thought that numbers of follicles do not vary between stages of the cycle. In contrast, Rajakoski (1960) suggested that antral follicles grow and regress throughout the oestrous cycle in two waves: the first ends around day 12 and is followed by atresia; the second culminates in oestrus.

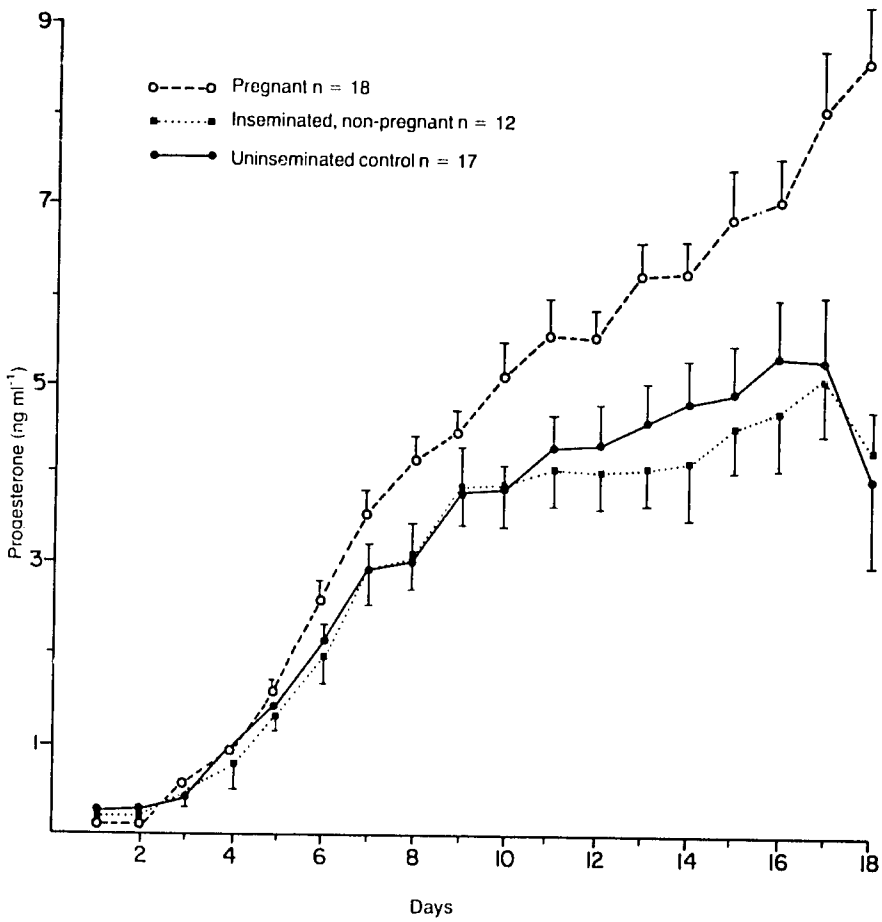
There is little information about prostaglandin concentration in zebu cows. Studies in the buffalo showed increases in prostaglandin concentration in blood plasma and milk from 250 to 900 pg/ml over the 2 or 3 days prior to oestrus (Batra and Pandey, 1983). Similar increases (150–750 pg/ml) were reported for the taurine cow by Kindhal et al (1976). Edquist and Kindhal (1981) give more information on the use of prostaglandins in animal reproduction.

2.2.3 Endocrinology of pregnancy

When a cow conceives, plasma and milk progesterone levels rise as in a normal oestrous cycle but instead of declining at about 15 to 18 days after oestrus, remain high for the rest of the gestation period, preventing further ovarian cycles (Peters and Lamming, 1983). Working with Holstein heifers, Hansel (1981) noted that jugular plasma progesterone concentrations were higher ($P < 0.05$) in pregnant than cyclic non-pregnant animals 10 days after oestrus (Figure 10), indicating that the bovine blastocyst is able to stimulate progesterone synthesis by as early as the 10th day after conception.

In a study of the blood progesterone levels during the gestation period of Ethiopian zebu cows, Mukasa-Mugerwa and Azage Tegegne (1989) (Figure 11) observed a trend similar to that found by Agarwal et al (1977, 1980) in Haryana Zebu and Coetzer et al (1978b) in Africander cows.

Figure 10. *Mean (± SEM) jugular plasma progesterone concentrations in pregnant, cyclic and inseminated non-pregnant heifers during an 18-day period*

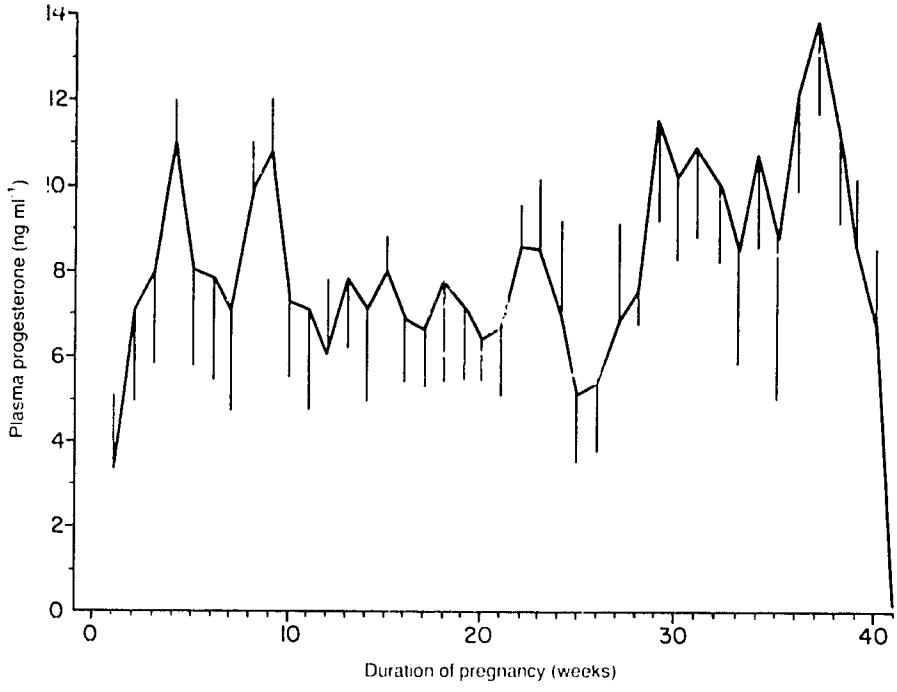


Source: Hansel (1981).

Progesterone levels in Ethiopian zebu cows were high (over 5 ng/ml) until the last 12 to 18 days of pregnancy. This was followed by a decline to 3.7–8.2 ng/ml one to two days before parturition. Hashmat and Shehata (1982) observed that progesterone levels declined to 1.2–2.0 ng/ml during the last 12–24 hours before calving and were less than 1 ng/ml 24–48 hours after delivery in local Egyptian cattle. The differences in progesterone concentration among the studies probably reflect breed and/or assay-technique variability.

Although the corpus luteum remains active throughout pregnancy its weight and progesterone content do not perfectly reflect changes in jugular plasma progesterone, indicating an extra-ovarian source (Erb et al, 1971). Abortion can be induced using prostaglandin $F_2\alpha$ ($PGF_2\alpha$) prior to 120 days of pregnancy (Dobson and Kamonpatana, 1986). After this time, both the placenta (Melampy et al, 1959) and adrenals (Wendorf et al, 1983) can produce progesterone. Progesterone from these sources probably maintains pregnancy after mid-term ovariectomy (Estergreen et al, 1967). These sources probably also account for the low abortion rates after

Figure 11. *Mean (± SEM) jugular plasma progesterone concentrations in zebu cattle during pregnancy*



Source: Mukasa-Mugerwa and Azage Tegegne (1989).

administering prostaglandins at 120 to 250 days of gestation, and the administration of $PGF_2\alpha$ is not very successful until after 250 days of pregnancy (Johnson, 1981).

Coetzer et al (1978b) reported that the level of unconjugated oestrogens was low (193 to 267 pg/ml) and fairly constant during pregnancy in Africander cattle. Between 2 and 6 days prior to delivery the level increased sharply to 271 to 523 pg/ml. The upper limit is comparable to the 501 pg/ml obtained by Stellflug et al (1978) for Angus and Hereford beef cows. Two days after parturition the level stabilised at around 110 pg/ml, with little variation between individuals. Erb et al (1971) had noted the same trend in taurine cattle. Substantial amounts of oestrogens are also produced by the bovine placenta after 100 days of pregnancy (Veenhuizen et al, 1960; Ainsworth and Ryan, 1966; Robertson and King, 1979; Evans and Wagner, 1981; Shelton and Summers, 1983).

2.2.4 Maternal recognition of pregnancy

The exact mechanisms involved in maternal recognition of pregnancy are not fully understood. However, it appears necessary that (i) corpus luteum function is maintained and (ii) the cyclic release pattern of LH must be terminated, prostaglandins must be stopped from reaching the corpus luteum, or some substance must be secreted to check the cyclic action of prostaglandins. It is suspected that interactions between the developing conceptus and maternal system are involved. The mechanisms regulating the establishment and maintenance of pregnancy in cattle must be understood before techniques can be developed to reduce the incidence of early embryonic mortality (Segerson et al, 1984a).

Plasma progesterone levels are significantly ($P < 0.05$) higher in pregnant than cyclic non-pregnant Holstein heifers by as early as 10 days after fertilisation (see Figure 10). Shemesh et al (1979) found that the bovine blastocyst can produce progesterone, some testosterone and limited amounts of oestradiol-17β by day 13 to 16. Blastocysts 15-17 days old are also able to convert androstenedione to oestrogen in vitro (Eley et al, 1979). Oestrogens have a luteolytic action in the cow (Wiltbank et al, 1961; Eley et al, 1979).

Homogenates of sheep embryos (Martal et al, 1979) and sheep conceptus secretory proteins (Godkin et al, 1984) can extend corpus luteum function and cycle length when administered into the uterine lumen of cyclic ewes. Thus, in sheep the pre-implantation embryo appears to produce a luteotrophic substance that contributes to the maintenance of early pregnancy by directly stimulating progesterone secretion by the corpus luteum. In cattle too, Knickerbocker et al (1986) found that treating cycling Holstein cows with conceptus secretory proteins extended the life-span of corpora lutea and inter-oestrus interval. An evaluation of spontaneous prostaglandin response suggested that proteins synthesised and secreted by the bovine conceptus accommodate luteal maintenance during early gestation via an attenuation of prostaglandin production. In sheep and cows, oestrogen, which is luteolytic in the late luteal phase, may indirectly induce uterine prostaglandin synthesis. The role of the embryonic hormone, which the above substance appears to be, may be to counter the lytic action of the prostaglandins. Further details on the subject and the proteins secreted are presented in Roberts and Parker (1974, 1976), Laster (1977), Segerson et al (1984a, 1984b), Thatcher et al (1984) and Roberts et al (1985).

2.2.5 Endocrinology of the postpartum period

The interval between calving and conception depends on the re-establishment of normal ovarian cycles after calving, the occurrence of oestrous behaviour at the appropriate time in the cycle, and the pregnancy rate following service (Peters, 1984).

The interval between parturition and ovulation is characterised by sexual quiescence (postpartum anoestrus). The duration of this interval varies with breed, milk yield level, animal age, suckling or lactating status, nutritional level before and after calving, season and associated photoperiodism, climate, health status and calving difficulty. Of these factors, nutrition and suckling appear to be very important.

Schallenberger et al (1978) noted that pregnancy reduces the sensitivity of the pituitary to GnRH. Sensitivity of the pituitary to GnRH increases only gradually after calving. The resumption of ovarian cyclicity depends on the establishment of a pulsatile pattern of LH secretion (Peters and Lamming, 1983). The observed delay is due, probably, to their being insufficient oestradiol to induce the pre-ovulatory LH surge (Peters et al, 1981).

2.2.5.1 Luteinising hormone

Peters and Lamming (1983) estimated that a pulsatile pattern of LH secretion with a frequency of 0.25 to 1 per hour appears to be a prerequisite for the first ovulation postpartum. This results in gradually increasing LH concentration before the first LH surge. Hansel and Alila (1984) stated that

the frequency of LH pulses is due to increased frequency of pulsatile releases of GnRH and that the factors affecting the duration of postpartum anoestrus also affect the time taken to establish the pulsatile pattern of LH release. Peters and Lamming (1986) thought that changes in gonadotrophin concentration may be brought about by changes in pituitary responsiveness to GnRH during the postpartum period. The time at which the pulsatile releases of LH appear and pituitary sensitivity increases varies among breeds and is also affected by suckling.

The exact mechanisms by which suckling interferes with the hypothalamus-hypophyseal axis are not well defined (Hanzen, 1986), but it is unlikely that teat manipulation alone can alter LH release patterns in the cow (Williams et al, 1984). Other factors, such as the presence of the calf or social interactions, might be necessary before teat stimulation has an effect (Hanzen, 1986). Suckling reduces the frequency and amplitude of LH release (Carruthers and Hafs, 1980), pituitary sensitivity to GnRH (Carruthers et al, 1978) and the pulsatile release of GnRH by the hypothalamus (Carruthers et al, 1980).

Suckling probably inhibits LH and GnRH release and their action rather than their synthesis (Hanzen, 1986). Both the hypothalamic concentration of GnRH and the pituitary concentration of LH are similar in milked and suckled cows (Carruthers et al, 1978; Saiduddin et al, 1967; Graves et al, 1968). Suckling can also inhibit the positive effect of endogenous or exogenous oestradiol on the release of pituitary LH (Short et al, 1979; Stevenson et al, 1983). Temporary weaning (48 hours) may, however, increase plasma LH concentration (Walters et al, 1982a), but LH concentration falls to previous levels within 4 hours of calf return (Walters et al, 1982b). Suckling delays LH release and reduces the amount of LH released in response to GnRH injection. Temporary calf removal can, however, enhance the total amount of LH released in response to GnRH injection (Dunn et al, 1985).

Using suckled beef cows, Rawlings et al (1980) noted that the maximum magnitude and frequency of LH peaks occurred 10 to 33 days before the initial increase of plasma progesterone, i.e. when there was a marked development of large follicles and a large variation in oestradiol-17β. These and similar observations have led researchers to (i) suggest that there might be a deficiency of GnRH during the early postpartum period and (ii) attempt to stimulate ovulation and ovarian cycles by repeated injections of GnRH (Peters and Lamming, 1986) in order to simulate the events of the preovulatory period. Results from GnRH treatment have been inconsistent (Riley et al, 1981; Walters et al, 1982b; Edwards et al, 1983). The number of animals, whether milked or suckled, that respond positively to GnRH injection increases during the postpartum period. Suckled cows are, however, less likely to respond during the initial 15 days than milked cows. This difference diminishes during subsequent weeks (Hanzen, 1986). After this period the magnitude of GnRH-induced LH release appears to be directly proportional to follicular development (Smith et al, 1983).

2.2.5.2 Oestradiol

It is difficult to monitor pulses of oestradiol-17β in the jugular vein. Peters and Lamming (1986) reported unpublished work in which cannulae were inserted into the posterior vena cava, anterior to the junction of the ovarian veins, of recently calved cows. Oestradiol-17β pulses, both naturally occurring and induced by three-hourly injections of GnRH, were detected: similar pulses could not be registered in the jugular vein, although increases

in oestradiol concentration were measured. It was concluded that the early postpartum cow is sensitive to GnRH-induced gonadotrophin release and responds by secreting oestradiol.

2.2.5.3 Progesterone

Two types of luteal activity have been observed in the postpartum cow. Fifty to 80% of milked or suckled dairy cows exhibit an initial luteal phase in which increases in plasma progesterone concentration are of shorter duration and progesterone concentrations are lower than in the normal cycle (Donaldson et al, 1970; Schams et al, 1978; Odde et al, 1980; Peters and Riley, 1982). This is referred to as the short luteal phase and lasts 6 to 12 days. The second luteal phase lasts about 14 days and tends to have lower than normal progesterone levels. This dual progesterone pattern occurs even after GnRH challenge (Fonseca et al, 1980), early weaning (Odde et al, 1980) or limited suckling with (Dunn et al, 1985) or without GnRH treatment (Flood et al, 1979).

Tribble et al (1973) thought that progesterone can be released from follicles that fail to ovulate. Schams et al (1978) felt that short progesterone cycles are caused by shortage of LH or its receptor. However, no differences in plasma LH concentration are observed before or after an oestrus associated with a short cycle (Ramirez-Godinez et al, 1982a). Troxel et al (1980) suggested that the short life-span may be the result of short GnRH-induced LH surges. Alternatively, the amount of LH receptor and number of granulosa cells may not be sufficient to give optimum response to this luteotrophic stimulus (Channing et al, 1981).

Hanzen (1986) pointed out that the corpus luteum from a cow with regular cycles responds positively in vitro to LH addition but that a corpus luteum formed after GnRH injection does not. This may be due to luteal tissue of the latter being unable to recognise LH (Kesler et al, 1981). It has been shown that the in vitro response of the postpartum corpus luteum during the first three cycles is related to the integrity of luteal tissue at the time of removal (Duby et al, 1985). These observations suggest that there may be premature luteolysis due to $PGF_{2}\alpha$ synthesised after calving by caruncular uterine tissue (Troxel and Kesler, 1984). It has been suggested that oxytocin can increase production of PGFM (a metabolite of $PGF_{2}\alpha$) and lead to earlier luteolysis (Troxel et al, 1984). Whatever the cause, the abnormal short cycles can result in increased early embryonic mortality (Ramirez-Godinez et al, 1982b; Troxel et al, 1983).

In a study of 20 postpartum pluriparous Brahman cattle, Rutter and Randel (1984) reported a higher incidence of abnormal cycles after the first heat than the second (35% vs 5%; $P < 0.05$). It was suggested that the higher incidence of abnormal luteal function following the first and second postpartum cycles contributes to lower conception rates in animals bred during the first or second postpartum heat.

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3. PUBERTY, OESTRUS AND PREGNANCY

3.1 Puberty

Puberty is a gradual quantitative phenomenon rather than an acute and qualitative endocrinological event. It occurs when the gonads begin to secrete sufficient steroids to accelerate the growth of the genital organs and the development of secondary sexual characteristics. Post and Reich (1980) defined puberty in *Bos indicus* heifers in Australia as the age at which plasma progesterone levels reach 1.0 ng/ml.

3.1.1 Importance and estimates of age at puberty

Age at puberty is an important determinant of reproductive efficiency. Many heifers, especially taurine, can reach puberty and breed fairly satisfactorily at one year old. However, the cost of achieving this varies among breeds and among heifers within the same breed. Heifers with the inborn ability to reach puberty early thus attain puberty and breed at less cost than those with later inherent age at puberty (Brinks, n.d.).

Estimates of age at puberty in *Bos indicus* cattle in the tropics and subtropics range between 16 and 40 months (Table 1). *Bos indicus* cattle reach

Table 1. *Some estimates of age at puberty among* Bos indicus *cattle in the tropics and subtropics*

Breed	Location	Estimate (months)	Source
Boran	Kenya	15.6	Ronningen et al (1972)
Africander	Louisiana (USA)	18.1	Reynolds et al (1963)
Mashona	Central Africa	19	Rakha et al (1970)
Sokoto Gudali	Nigeria	19.0–23.5	Oyedipe et al (1982)
Brahman	Florida (USA)	19.4	Plasse et al (1968a)
Angoni	Central Africa	20	Rakha et al (1970)
Africander	Central Africa	20	Rakha et al (1970)
Kankrej	India	22.5	Fulsounder et al (1984)
Zebu	Ethiopia	22.6	Alberro (1983)
Brahman	Venezuela	23.3	Ordonez et al (1974)
Boran × Sahiwal	Tanzania	26	Macfarlane and Worrall (1970)
Brahman	Louisiana (USA)	27.2	Reynolds et al (1963)
Haryana	India	30	Ahuja et al (1961)
Zebu	Somalia	31.5	Aria and Cristofori (1980)
Gir	India	36.5	Malik and Ghei (1977)
Red Sindhi	India	36.7	McDowell et al (1976)
Ankole	Rwanda	37	Compere (1963)
White Fulani	Nigeria	40.2	Knudsen and Sohael (1970)

puberty later than *Bos taurus* × *Bos indicus* crossbreeds or purebred taurine cattle (Table 2). This is due to genetic and environmental factors, including nutrition, disease, temperature and season of birth. These factors affect heifer growth rates.

Table 2. *Some estimates of age at puberty among* Bos taurus *cattle and their crosses with* Bos indicus *types in the tropics and subtropics*

Breed	Location	Estimate (months)	Source
Brown Swiss	Rwanda	8–15	Compere (1963)
Jersey	India	14.1 ± 0.[illegible]	McDowell et al (1976)
Angus	USA	14.4	Reynolds et al (1963)
3/4 *Bos taurus* cross	India	14.5 ± 0.23	McDowell et al (1976)
Brahman × Angus	USA	15.3	Reynolds et al (1963)
1/2 *Bos taurus* cross	India	15.3 ± 0.23	McDowell et al (1976)
1/4 *Bos taurus* cross	India	16.8 ± 0.46	McDowell et al (1976)
Brahman × Shorthorn	Florida (USA)	17.0	Plasse et al (1968a)
F_1 crosses	Ethiopia	17.0 ± 1.5	Alberro (1983)
Africander × Angus	USA	18.1	Reynolds et al (1963)
3/4 Friesian × 1/4 Zebu	Trinidad	19	Duckworth (1949)
Brahman	Florida (USA)	19.4	Plasse et al (1968a)
Pure Friesian	Nigeria	19.5	Knudsen and Sohael (1970)
3/4 Friesian × 1/4 White Fulani	Nigeria	20.0	Knudsen and Sohael (1970)
1/2 Friesian 1/2 White Fulani	Nigeria	21.2	Knudsen and Sohael (1970)
Crossbreeds	South America	22.5	Linares et al (1974)
Brahman × Criollo	South America	23.3	Ordonez et al (1974)
Crossbreeds	Somalia	24.5	Aria and Cristofori (1980)
Ankole × Jersey	Rwanda	26.5	Compere (1963)

3.1.1.1 Genetic factors affecting puberty

Age at puberty varies among species, breeds and even strains and families. On average, the zebu reaches puberty 6 to 12 months later than *Bos taurus* cattle (Warnick, 1965; Wiltbank et al, 1969). Temperate taurine breeds of dairy cattle reach puberty at 30–40% of their adult body weight, compared with 45–55% for beef cattle (Hafez, 1980). In contrast, ranched Boran zebu heifers in Ethiopia do not attain puberty until they reach 60% of their adult bodyweight. Zebu heifers raised traditionally attained puberty at an even higher percentage of adult weight.

Estimates of the heritability of age at puberty range from 0.20 to 0.67 (Arije and Wiltbank, 1969; Smith et al, 1976; Laster et al, 1979; Rathi, 1979; Werre, 1980; Lunstra, 1982; King et al, 1983). Heritability of weight at puberty ranged from 0.30 to 0.44.

Several studies, particularly among taurine cattle, have attempted to relate age at puberty with other production traits. Werre (1980) found

strong, negative genetic correlations between age at puberty and measures of growth: faster growing heifers reached puberty earlier. Genetic relationships with average daily gain to weaning, weight at puberty and yearling weight (−0.31 ± 0.82, −0.44 ± 0.41 and −0.25 ± 0.70, respectively) were stronger than the phenotypic correlations (−0.13, 0.07 and −0.03, respectively). Thus, heifers growing faster for genetic reasons are likely to be younger and heavier at puberty. Arije and Wiltbank (1971) and Steffan et al (1983) reached similar conclusions.

Wiltbank et al (1966) observed that the breed of sire and dam and their interaction affected age and weight at puberty. Laster et al (1972) thought that both heterosis and maternal effects (lactation and mothering ability) affected age, but not live mass, at puberty.

Reynolds et al (1963) estimated the average age at puberty in Brahman heifers in Louisiana, USA, to be 27.2 months, compared with 14.4 months for Angus heifers. The estimate for Angus × Brahman crosses was 15.3 months (26.4% heterosis). McDowell et al (1976) calculated heterosis in age at puberty to be 18.4% among Red Sindhi × Jersey crosses in India. Ordonez et al (1974), working with Brahman × Criollo crosses in Latin America, ascribed the heterotic effect on age at puberty to better growth rates in the crossbreds.

3.1.1.2 Environmental factors affecting puberty

Nutrition and bodyweight

The major factors controlling the onset of puberty are body weight and growth rather than age (Sorensen et al, 1959; Boyd, 1977; McDonald, 1980): until heifers reach a particular (target or critical) weight, oestrus is unlikely to occur. Short and Bellows (1971) observed high pregnancy losses and low milk production in heifers that were fed poorly prior to puberty.

Poor nutrition significantly delays puberty in both zebu (Morales et al, 1977; Mancio et al, 1982; Oyedipe et al, 1982) (Table 3) and taurine cattle (Joubert, 1954; Sorensen et al, 1959; Bedrak et al, 1969; Short and Bellows, 1971).

Table 3. *Age and weight at puberty and conception among Nigerian zebu heifers on high, medium and low levels of dietary protein intake*

	High[1]	Medium[1]	Low[1]
Age at puberty (days)	570.4	640.8	704.2*
Weight at puberty (kg)	207.1	187.0	161.7*
90-day conception rate (%)	58.8	27.8	16.7*
Weight at conception (kg)	240.0	240.2	248.0
Age at conception (days)	624.3	759.0	930.8*

* Differences between treatments significant at $P < 0.05$.

[1] The high, medium and low rations contained 150, 100 and 41% of estimated requirements, respectively

Source: Oyedipe et al (1982).

Heifers on a high-protein diet are often younger and heavier at puberty than those on a low-protein diet (Sorensen et al, 1959; Wiltbank et al, 1966; 1969; Garcia and Calderon, 1978) and are more fertile after puberty. However, although poor nutrition delays puberty, very high levels of

feeding do not necessarily result in earlier puberty than adequate levels. No data are currently available that indicate how much energy or protein zebu heifers need daily to achieve a given weight and puberty at a given age. The role of nutrition on pubertal development is detailed in Chapters 4 and 6.

Disease and parasite burdens

Post and Reich (1980) studied the effects of parasite burden and reproduction in 212 heifers from 10 breed groups in Australia. The animals were grazed in 4 groups: (1) control with no treatment for gastro-intestinal or ecto-parasites; (2) treated monthly with an acaricide against ecto-parasites; (3) treated monthly with an anthelminthic for endo-parasites; and (4) treated monthly with both acaricide and anthelminthic. By 25 months, 197 of the 212 heifers had reached puberty (Table 4). Weight at puberty differed significantly ($P < 0.05$) among treatment groups but age did not. No significant interactions were recorded between breed and treatment for either age or weight at puberty. Similar data for traditionally raised zebu cattle, in which both problems are often more prevalent, are not available.

Table 4. *Effect of acaricide and anthelminthic treatment on age and weight at puberty*

Treatment	n	Number attaining puberty	Age (days)		Weight (kg)	
			Mean	Range	Mean	Range
No treatment	50	45	557	413–735	253[a]	158–338
Acaricide	56	47	533	328–760	253[a]	169–330
Anthelminthic	50	50	511	390–670	262[ab]	169–398
Anthelminthic + acaricide	56	55	522	340–735	274[b]	163–360
Overall	212	197	530	328–760	261[b]	158–360

In the mean weight column, means without at least one common superscript are different ($P < 0.05$).

Source: Modified from Post and Reich (1980).

3.1.2 Anomalies in age at puberty

In some heifers, first oestrus, conventionally the first sign of puberty, is not followed by ovulation and a number of oestrous periods may occur before the start of persistent cyclic ovulation. This phenomenon of "adolescent sterility" was referred to by Rutter and Randel (1986) as non-pubertal oestrus (NPO) – behavioural oestrus without subsequent development of functional luteal tissue.

NPO was demonstrated by Macfarlane and Worrall (1970) in Boran and Boran × Sahiwal heifers in Tanzania. The NPO period was significantly longer ($P < 0.001$) during the dry season (Table 5) which suggested that nutritional status might be involved.

Of 43 Simmental × Hereford-Brahman heifers studied by Rutter and Randel (1986) in Texas, USA, 27 (62.8%) exhibited NPO after their first behavioural oestrus. NPO tended to be more common in light-weight heifers than in heavier heifers ($P = 0.12$).

Table 5. *Interval between first oestrus and ovulation in Boran and Boran × Sahiwal heifers in Tanzania*

	n	Interval (days)	C.V. (%)
Rainy season	56	67.0	16.9
Dry season	24	103.4	24.5

Source: Macfarlane and Worrall (1970).

After first oestrus (puberty), the ability of heifers to conceive improves with age, reaching optimum levels at sexual maturity. Thus, although oestral activity was exhibited at 15.6 months in Boran cattle at Muguga in Kenya, first service was delayed until 21.7 months (Ronningen et al, 1972).

3.2 The oestrous cycle

3.2.1 Oestrous cycle length

The oestrous cycle comprises all events related to reproduction occurring between two periods of sexual activity. But this definition can be erroneous in the cow as it overlooks silent heats, which Plasse et al (1970) found in 26% of Brahman cows studied in the Florida Gulf Coast area of the USA, and fails to accommodate very early embryonic mortality, both of which can increase oestrous cycle length.

Several efforts have been made to define the length of the oestrous cycle of zebu cattle. Anderson (1936, 1944) reported the normal range to be 17 to 24 days in zebu cattle in Kenya. Cycle lengths within this range have since been reported by several other investigators (Table 6).

Cycle length has generally been determined by monitoring cow sexual behaviour but similar information can be obtained by palpating ovarian structures or by measuring progesterone levels (Martinez et al, 1984; Llewelyn et al, 1987). Cycle length varies among breeds and animals within a breed, and with season, nutrition, disease, age, management and cow production status. For example, Zakari et al (1981) analysed 379 oestrous cycles of 4- to 5-year-old Bunaji (White Fulani) and Bukoloji (Sokoto Gudali) cows in Nigeria. Average cycle length was 22.87 ± 0.70 and 23.76±0.65 days, respectively. There was no significant ($P > 0.05$) difference in cycle length between the breeds within season but cycles were significantly longer during the dry (pre-rainy) season than at other times of the year ($P < 0.01$). A similar trend was observed by Rakha and Igboeli (1971) in Central Africa. Rectal palpation of animals failing to return to oestrus showed that 55% had developed quiescent ovaries. Ovaries were functional in the remaining 45% but it was not clear what proportion might have been exhibiting silent heat. The associated bodyweight changes that would have given more information on the physical condition of animals failing to show oestrus were not reported. However, Baker (1967, 1968) observed that Sahiwal × Shorthorn heifers showing oestrus were heavier ($P < 0.01$) in any month than anoestrous heifers (Table 7) and Bartha (1971) reported more irregular cycles in Azaouak cows that had high milk yields or that had lost a lot of weight postpartum.

Zakari et al (1981) found that about 43% of the oestrous cycles occurred during the rainy season, 25% during the pre-dry, 19% in the dry and only

Table 6. *Some estimates of oestrous cycle length in* Bos indicus *cattle*

Breed	Location	Estimate (days)	Source
Zebu	Cuba	17–31	Martinez et al (1981)
Africander	South Africa	19.3–21.7	Coetzer et al (1978)
Zebu	Zambia	19.6 ± 1.2 to 22.0 ± 1.5	Rakha and Igboeli (1971)
Indu Brazil	Mexico	20 ± 1.9	Vaca et al (1985)
Azaouak	Sahel	20–22	Bartha (1971)
Zebu	Kenya	20.1	Anderson (1936)
Dangi	India	20.4 ± 0.2	Purbey and Sane (1978a)
Nganda	Uganda	20.9 ± 1.4	Rollinson (1963)
Garre	Somalia	21.5	Aria and Cristofori (1980)
Bunaji cross	Nigeria	21.5 ± 3.4	Johnson and Oni (1986)
Angoni	Zambia	21.9	NCSR (1970)
Small East African Zebu	Ethiopia	22.2 ± 6.0	Mattoni et al (1988)
White Fulani	Nigeria	22.4 ± 0.7	Johnson and Gambo (1979)
Grade	Kenya	22.42	Anderson (1944)
Sahiwal	Somalia	22.5	Aria and Cristofori (1980)
White Fulani	Nigeria	22.9 ± 0.7	Zakari et al (1981)
Boran	Kenya	23 ± 0.4	Llewelyn et al (1987)
Zebu	Kenya	23.03	Anderson (1944)
Bunaji	Nigeria	23.4 ± 2.7	Johnson and Oni (1986)
Red Sokoto	Nigeria	23.8 ± 0.6	Zakari et al (1981)
Zebu	Cuba	24.2 ± 10.7	Martinez et al (1984)
Zebu	Ethiopia	25.1 ± 6.0	Alberro (1983)

Table 7. *Average bodyweight of oestrous and anoestrous Sahiwal × Shorthorn heifers, Queensland, Australia, November 1964 to June 1965*

Month	Average bodyweight (kg)	
	Oestrous heifers	Anoestrous heifers
November 1964	313	284
December	335	273
January 1965	315	291
February	320	258
March	321	301
April	331	289
May	358	306
June	337	314

Source: Baker (1967).

12% in the pre-rainy period. In India, Purbey and Sane (1978a) recorded that about 40% of the oestrous cycles in Dangi cows occurred in the summer, 34% in the winter and 26% in the monsoon season. These differences might have been due to fluctuations in nutrition level but the periods when oestrus was irregular and less frequent were also characterised by low relative humidity, high ambient temperature and increased sunshine.

Kaikini and Fasihuddin (1984), using Sahiwal and Gir cows in India, and Hutchison and Macfarlane (1958), working with Boran and other unspecified zebu cattle in Tanzania, found that 3 to 7.5% of pregnant cattle exhibit a gestational oestrus. These are aberrant cycles with no ovulation or corpus luteum formation[1].

[1] R D Randel, Texas A & M University, College Station, Texas, USA, personal communication.

3.2.2 Oestrus duration

The mean duration of oestrus in zebu cattle is around 10 hours, but with a range of 1.3 to 20.0 hours (Table 8). Estimates of the duration of oestrus in *Bos taurus* cattle in the tropics and subtropics range from about 11 hours to about 15 hours (Hall et al, 1959) with intermediate values being reported by Esslemont and Bryant (1976) and Blanton et al (1957). The wide variation in the duration of oestrus in zebu cattle partly reflects variation in the observation methods and actual breed peculiarities of oestrus in zebu cattle, some of which are highlighted below.

Table 8. *Some estimates of the duration of oestrus in zebu cows*

Breed	Location	Estimate (hours)	Source
Zebu	Kenya	1.3 to 4.78	Anderson (1936)
Nganda	Uganda	2.2	Rollinson (1963)
Small East African Zebu	Ethiopia	2.53 to 7.36	Mattoni et al (1988)
White Fulani	Nigeria	3.1 ± 0.2	Johnson and Gambo (1979)
Bunaji	Nigeria	3.6 ± 2.2	Johnson and Oni (1986)
Bukoloji	Nigeria	4.03 ± 0.96 to 10.70 ± 0.92	Zakari et al (1981)
Zebu	Ethiopia	4.5 ± 2.2	Alberro (1983)
Brahman	USA	4–6	Warnick (1965)
Bunaji	Nigeria	5.15 ± 0.92 to 11.44	Zakari et al (1981)
Brahman	USA	6.7 ± 0.8	Plasse et al (1970)
Bunaji cross	Nigeria	8.2 ± 2.8	Johnson and Oni (1986)
N'Dama	Ivory Coast	8–9	Ralambofilinga (1978)
Zebu	Central Africa	13.3 ± 0.22 to 16.5 ± 1.0	Rakha and Igboeli (1971)
Shorthorn	Australia	13.4 ± 0.7	Baker (1967)
Zebu	Cuba	14.3 ± 3.1	Solano et al (1982)
Zebu	Cuba	15.3 ± 4.3	Martinez et al (1984)
Zebu crosses	Latin America	15.3 ± 4.37	Morales et al (1983)
Zebu	Cuba	15.3 ± 4.4	Martinez et al (1981)
Angoni	Zambia	16.3	NCSR (1970)
Barotse	Zambia	17.4	NCSR (1970)
Zebu	Mexico	20 ± 1.9	Vaca et al (1985)

Heat stress causes low intensity oestrus in zebu and, sometimes, *Bos taurus* cattle raised in the tropics (de Alba et al, 1961). NCSR (1970) and Cuq (1973) also noted that oestrus in zebu cattle tends to be subdued, with few external signs. In a general review of oestrus in tropical zebu cattle, Cuq (1973) estimated that 30–40% of oestrous activity occurred at night, which agrees with the 34.8% reported by Rollinson (1963) among Nganda cattle in Uganda.

Rollinson (1963) calculated the average duration of pro-oestrus and meta-oestrus to be 14 and 11 hours, respectively, compared with 3.5 ± 1.5 and 2.8 ± 0.7 hours obtained by Baker (1967) for Sahiwal × Shorthorn crosses and 3 to 3.5 hours by Mattoni et al (1988) for the Small East African Zebu in Ethiopia.

Rollinson (1963) found that although cows may remain attractive to bulls for an average of 27 hours, they stood for service for only 2.2 hours. Nearly a third (31.2%) of the heats started between 0600 and 1000 hours. Cows were most active soon after day-break. Similar observations were reported by Zakari et al (1981) in Nigeria and Solano et al (1982) in Cuba. Orihuela et al (1983) observed that up to 63% of mounts occurred at night (1800 to 0600 hrs) in zebu cows in Mexico. All these studies show that many of the heats start when animals are confined for the night and would be undetected by daytime observation only. Moreover, in the cooler Ethiopian highlands, Mattoni et al (1988) observed that, although 63% of heats started during the day, mounting activity was greatest when cows were not grazing. There thus appears to be a breed × environment interaction on oestrus manifestation in zebu cows. High daytime temperatures and the need for feed appear to have a strong influence on oestrus onset.

Oestrus can be prevented by psychological influences (Boyd, 1977). An animal used to being bullied may be unwilling to stand for riding, as will animals with painful lesions of the limbs or back. Hunger or extreme weather conditions may prevent an animal from expressing heat or non-oestrous animals from mounting those in oestrus. These factors act on both the male and the female.

3.2.3 Oestrus detection

Accurate detection of oestrus is essential for effective reproductive management, particularly where artificial insemination or hand mating is practised. Poor heat detection can cause increased levels of apparent or managemental infertility.

In a controlled breeding experiment in Sri Lanka, Abeyratne et al (1983) found that most farmers were unaware that their animals were displaying oestrous cycles. About 10% of the non-pregnant animals were in heat when examined prior to treatment. In many cases animals had been seen in heat, served, and assumed pregnant, and subsequent oestrous cycles were overlooked. Many of the farmers kept only one or two breeding females, either tethered or confined. They used mainly bellowing, restlessness and mucous discharge or mounting by the bull to identify oestrus. Zemjanis et al (1969), working in Venezuela, estimated that 90% of animals thought to be anoestrous were actually cycling.

The heat detection method used should identify oestrus simply, accurately and positively. Successful heat detection is possible only when cows can be correctly identified, proper records are maintained, stockmen are properly trained and sufficient time is spent watching for oestrus.

Esslemont et al (1985) recommended that in order to improve heat detection among *Bos taurus* cattle, it is useful to watch for heat three or four times a day, leaving not more than 8 hours between visits. Such a system improves heat detection rates to 80% (Table 9). In a study of 1460 oestrous periods in 270 Holstein-Friesian dairy cows and heifers in Louisiana

Table 9. *Effect of number and times of observation on heat detection among temperate* Bos taurus *cows*

Number of observations	Observation time					Detection rate (%)
2	0600		1800			69
3	0600	1400	2200			84
4	0600	1200	1600	2000		86
5	0600	1000	1400	1800	2200	91
2	0800		1600			54
2	0800		1800			58
2	0800		2000			65
3	0800	1400	2000			73
4	0800	1200	1600	2200		80
4	0800	1200	1600	2000		75

Source: Esslemont et al (1985).

(USA), Hall et al (1959) found that 10% more oestrous periods were detected if the cows were checked three times daily (at 0600, 1200 and 1800 hours) than when checked twice a day (at 0600 and 1800 hours). A fourth check (at 2400 hours) resulted in an increase of nearly 20% compared to twice-daily checks.

Oestrus can be detected by visual, non-visual, hormonal and laparascopic means. Visual methods are covered extensively here because they constitute some of the first steps for improving reproductive performance.

3.2.3.1 Visual methods and aids to heat detection

Esslemont et al (1985) identified the following pattern in the oestral behaviour of taurine cows:

- Licking and rubbing each other.
- Sniffing the vagina of another cow.
- Mutual chin resting.
- Lining up to mount another cow.
- Mounting another cow.
- Standing to be mounted by another cow.

This is a general pattern only and not a sequence of events to expect in individual cows. In taurine or taurine × zebu cows the most characteristic signs to look for are standing to be mounted and mounting head to head.

Other signs of heat are less reliable. Cows in oestrus tend to be restless and nervous, and to feed less, and their milk production may also fall. They sniff the vulva or urine of other cows. They bellow, lick and bunt and may urinate more frequently (dribbling). In large herds a few, usually restive, cows tend to congregate and mount each other. Animals standing for mounting often develop a ruffling and abrasion of the hip, rump or pin bone hair (muddy, rubbed back and sides). Some cows discharge copious quantities of mucus from the vagina. The vulva of an oestrous cow

may become swollen, soft and reddened, particularly if the cow is repeatedly mounted by a bull.

Changes in the amount of oestrogen secreted by the cycling cow are, probably, the main cause of variations in the visible signs of oestrus. From 2 to 3 days before oestrus until oestrus, oestrogen increases blood supply to the uterus and increases uterine tone and turgidity, relaxes the cervix, increases cervical mucus production and the number of endometrial glandular cells and initiates oestrous behaviour. Therefore, shortage of oestrogen may lead to failure or reduced intensity of oestrus symptoms, or short oestrus. Alternatively, low levels may fail to trigger the luteinising-hormone surge necessary for ovulation and the mature follicle would become atretic or cystic.

Rollinson (1963) found that zebu cows remain attractive to bulls for 12.1 to 38.3 hours, with variations both within and among animals. Over this period cows were successfully mounted an average of 4.4 times (range 1–11). The total number of mounts, including those without intromission, averaged 9.5 (range 1–28). The author suggested that the limited number of actual, rather than attempted, mounts was due to the short duration of oestrus relative to pro- and meta-oestrus in zebu cattle. This is supported by Esslemont and Bryant (1976) who found that taurine cattle, which tend to have a longer oestrus, were mounted 56.3 ± 34.8 times.

Oestrus is difficult to detect in zebu cattle, probably because their highly organised social hierarchy is disturbed by changes in management, such as the introduction of a teaser bull not known to the herd or removing animals from their natural environment. Galina et al (1982) reported that zebu cattle do not allow themselves to be ridden repeatedly. Animals studied averaged only 1 mount per hour compared with 2.8 mounts per hour for Charolais. Mattoni et al (1988) estimated an average of 8 mounts per hour for the Small East African Zebu but with a range of 1 to 58. Up to 5% of heats were characterised by a single mount.

The number of cows in heat at any time, and the type of bull or teaser, can also affect oestrous behaviour. For example, Esslemont et al (1985) observed that among *Bos taurus* cattle, the number of mounts per cow tends to be greatest when three animals are in heat at the same time, and then declines. Johnson and Oni (1986) observed oestrous behaviour in Bunaji and Bunaji × Friesian heifers over 96 days using either vasectomised bulls or herd-mates as teasers. The animals were watched from 0600 to 1200 and 1300 to 1800 hours daily. The number of mounts per heifer over the study period ranged from 68 to 170. Crossbred bulls mounted crossbred heifers more than did Bunaji bulls or herd-mates: they averaged 28.3 ± 5.3 mounts with crossbred heifers, compared with 24.5 ± 4.9 and 22.0 ± 4.6 mounts by Bunaji bulls and herd-mates, respectively. The pattern was the same with Bunaji heifers, crossbred bulls averaging 21.4 ± 4.6 mounts compared with 18.6 ± 4.3 and 16.4 ± 4.1 mounts by the other two teaser types.

De Alba et al (1961) noted that some zebu cows refused to be mounted more than once during oestrus. Orihuela et al (1983) also observed that 85% of riding behaviour was by cows in heat. Some zebu cows change their oestrous behaviour when confined. In a study of 10 primiparous 3-year-old Boran cows, Llewelyn et al (1987) found that behavioural signs were only 27% accurate in indicating oestrus, although this appears to be a very low estimate.

In a study of ovarian function and oestrous behaviour involving 15 oestrous cycles of 5 zebu heifers in Zimbabwe, Symington and Hale (1967) observed clear sticky mucus in the vaginas of 5 heifers 2 days

before oestrus and of 3 heifers 2 days after oestrus. At other times the vagina contained varying amounts of cream-coloured mucus. The volume of mucus was less and its consistency looser during the luteal phase of the cycle. In a study of Ethiopian Highland Zebu type cows, Mattoni et al (1988) found mucus discharge in only 64% of the oestrous periods. The appearance of the mucus may at times be haemorrhagic. Larger amounts tend to be discharged when the oestrous cow mounts others, lies down or urinates. It can thus be easily missed, especially at night. At other times, the only evidence of vaginal mucous discharge may be a pasting of the tail and/or legs. Therefore, although vaginal mucus discharge can be a useful indicator of oestrus, it is not precise.

The intensity of signs of oestrus appears to be related to conception rates. Hall et al (1959) used a scale of 1 to 3 to score intensity of oestrus:

1. Thin, glary vaginal discharge, nervousness, and unusual interest in herd-mates
2. More intense periods with increased vaginal discharge, considerable excitement and mounting of other females
3. The animal stands to be mounted, with or without the symptoms given for (1) or (2).

In a study 3/4 Holstein-Friesian × 1/4 zebu cows, Morales et al (1983) observed conception rates of 66, 50 and 93% ($P < 0.05$) in animals showing weak, moderate and strong signs of oestrus.

The fact that few herders are properly trained to detect heat, the difficulty in identifying the signs of heat in zebu cattle, the large variability in the duration of oestrus, plus the reluctance of some bulls to mate, all make heat detection a major problem in peasant herds. These herds comprise few animals, sometimes a single cow, an ox and a yearling bull or a heifer. In such cases the best chance of detecting cows in heat would be at the communal grazing pastures when animals interact with others from elsewhere. However, daytime observations alone will miss those animals that exhibit oestrus at night, i.e. roughly one-third of the herd. In addition, animals are often not taken to pasture until late morning. As a result, several heats would be missed, some cows fit for insemination may not be presented, a few would be inseminated when they are actually pregnant and some would be inseminated during the luteal phase of the oestrous cycle. All of these factors contribute to poor results where artificial insemination or hand mating are used as the breeding methods. Several devices have, therefore, been developed that aid visual recognition of oestrus. Some are discussed below.

Tail paint marks

In the tail-paint-mark system, a strip of paint is applied to the rump of the cow: when the cow is mounted the paint becomes scuffed or cracked. For large taurine breed cows the paint is applied in a strip 20 cm long and 5 cm wide running from a point 12 to 15 cm behind the level of the tuber coxae towards the tail along the mid-line. Anatomical variations between breeds may lead to slight differences in the best position to place the paint mark.

The paint is stripped into the hair and should reach the skin. The animals should be examined at least daily to determine whether they have been mounted. With experience, the cracking pattern of the paint can be used to estimate the time at which the animal was in heat.

Although several special paints or pastes are commercially available, ordinary high gloss enamel, paste or water-based paint can be used

successfully. Where ordinary household paint is used it should be applied every 3 or 4 days.

Kerr and McCaughey (1984) found the tail painting method to be 88% accurate in a study in which oestrus was also determined by regular progesterone assay. Smith and MacMillan (1980) reported 99% accuracy, 33% higher than the rate of detection by farmers using behavioural observation alone. Given the ease with which these paints can be acquired, they should be used more often.

Chinballs and harnesses

Chinball markers or harnesses (Elmore et al, 1986) consist of a halter, worn by the bull or teaser, with a built-in "roller ball" or crayon that leaves a strip of paint on the back of the cow after mounting. The crayons must be replaced regularly. If commercial crayons are not easily available, crayons can be made from beeswax (20%), stearic acid (15%), oleic acid (10%), mineral filler, such as asbestos powder or talc (50%) and pigment (5%). The pigment must be insoluble. A softer product can be made by reducing the proportion of stearic acid relative to oleic acid.

Chinballs or harnesses are normally used on "prepared" teaser animals, e.g. epididectomised or vasectomised bulls, bulls with an amputated penis, a penile deviation, a preputial stenosis (pen-o-block), or a penis which is anchored posteriorly or ventrally to the scrotum, and steers injected with oestrogen or testosterone.

Androgenised cows (treated with male hormones) have been used as teaser animals. Kiser et al (1977) administered testosterone for 20 days (inducing regime) followed by a maintenance dose every 10–14 days. Alternatively, a single intra-muscular injection of 200 mg testosterone anathate can be used, followed by a booster after 3 to 4 weeks (personal experience). Such cows, which should not be milking, marked others in heat as effectively as surgically prepared bulls. Nymphomaniac cows or heifers that are cystic can also be used as teasers. Hackett and Lin (1985) used oestrogen, in addition to testosterone, to prepare teaser cows.

Because they actually serve the cow, vasectomised bulls can transmit venereal diseases. Their libido may also decline when they are used over several seasons. Bulls with a deviated penis offer a safer alternative since they mark cows without intromission, but they may also lose libido and a few have been observed to serve cows by mounting at an angle.

Three or four teasers should be used per 100 cows. They should be worked in groups with frequent rest. Bulls within a group should be moved frequently to avoid the formation of favourite units.

Marking web device

The marking web device is a simple and reliable oestrus detection aid recently reported by Broadbent et al (1989). It is constructed from a piece of calico (8.5 × 8.0 cm) and an 8.5 × 2.5 cm strip of household tape, covered by a layer of black mastic, stuck across the calico. The device is fixed to the sacral region of the cow or heifer using a suitable adhesive. Pressure from the chest of the animal mounting peels the mastic from the underlying tape. When tested on two groups of heifers kept at pasture (n = 22) or indoors (n = 134), the device was found to be 86 and 59% as accurate, respectively, as four times per day visual observation; there were 14 and 41%, respectively, of false positives, but no false negatives.

3.2.3.2 Non-visual methods

Rectal palpation

An experienced practitioner can predict when a cow is likely to come into heat by rectal palpation of the ovaries and uterus. Care has to be exercised in examining zebu cows because their ovaries tend to be smaller than those of *Bos taurus* cows. Rectal palpation is more effective in heifers because their ovaries tend to be smaller and smoother than those of older cows and the corpus luteum (CL) and follicles can thus be identified more easily. Rectal palpation is particularly valuable because bulls may fail to detect heat in some cows with apparently normally functioning ovaries (Symington and Hale, 1967). This could arise from silent heats, bull exhaustion, too many cows per bull or the physiological inability of oestral cows to attract bulls.

Five stages can be differentiated by rectal palpation during a 21-day oestrous cycle: (1) pro-oestrus (days 17–20), (2) oestrus (day 1), (3) early meta-oestrus (day 2), (4) late meta-oestrus (days 3–6), and (5) di-oestrus (days 7–16).

During pro-oestrus, a growing follicle and a regressing CL can both be felt. They may be on the same ovary or on different ovaries. The uterus feels swollen and its turgidity is increasing. Such a cow should be expected in heat in 1 to 4 days. For increased accuracy the cow should be palpated every 6 to 12 hours.

During oestrus the ovary has a mature follicle and a CL that is almost completely regressed. On palpation, the uterus is very turgid, or responds by toning up. Oxytocin released after gentle palpation causes the smooth musculature of the oestrogen-sensitised uterus to contract. Rough palpation can, however, cause the release of adrenalin, which would inhibit this response. The uterus must, therefore, be massaged gently to elicit response (Studer, 1975). When this condition is observed, the cow should be inseminated.

In early meta-oestrus, an ovulation fossa or depression can be felt on the ovary. However, this can be difficult to detect unless the ovaries have been repeatedly palpated near to oestrus to establish the presence, size and side of the follicle. There are often no other palpable structures, but it may be possible to detect a regressing CL and small follicles. The uterus is swollen and the tone decreasing. Such an animal can be expected in heat after 19 days. During late meta-oestrus the ovary has a new developing CL from the previous ovulation. Uterine tone is greatly decreased. Such cows can be expected in heat after 15 to 18 days.

In di-oestrus, ovaries have a mature CL and small follicles may or may not be palpable. The uterus is flaccid. Such cows can be expected in heat after 5 to 14 days.

A common problem in the zebu is failure to estimate the age of the CL. Symington and Hale (1967) suggested that the aberrant behaviour of the zebu CL may indicate that ovarian hormonal activity is less intense or that the morphological changes of the ovary are less pronounced than in taurine cattle.

The follicle is smooth and fluctuant and blends evenly into the ovary. In contrast, the CL is liver-like (friable) in consistency and often has a clear line of demarcation between itself and the ovary and, often, a crown. The CL also tends to change the size and shape of the ovary while the follicle usually does not.

Cervical or vaginal mucus crystallisation characteristics

Goel and Rao (1971) studied the characteristics of 88 samples of mucus, collected at different stages of the oestrous cycle of zebu cattle in India, and concluded that their crystallisation pattern (arborisation) could be used to detect oestrus.

In samples of cervical and vaginal mucus collected daily from day 16 of the oestrous cycle until ovulation, Alliston et al (1958) found that the crystallisation patterns before and after oestrus were "fern-like", and were more visible near oestrus than during the luteal phase. This pattern appeared 3.5 days (84 hours) before oestrus and started to decline before ovulation. Crystallisation patterns of vaginal mucus were less reliable indicators of oestrus than those of cervical mucus in a study in which the pattern was also related to rectal palpation findings (Bane and Rajakoski, 1961).

Although oestrus and ovulation were associated with "fern-like" patterns of air-dried cervical mucus from cows in Zimbabwe, Donkin (1980) observed that the same patterns may occur at other times in the cycle. Ghannam and Sorensen (1967) found the mucous pattern method useful only for pregnancy diagnosis.

Cervical mucus glucose content was studied by Symington and Hale (1967) in zebu heifers in Rhodesia using Clinistix strips (Ames). Pooled information from all animals indicated a tendency for the glucose test to be more positive on day 0 than at other times. However, there was a large variation in individual results, leading to the conclusion that cervical mucus glucose content is of little predictive value.

Cervical or vaginal mucus resistance and conductivity

Changes in the electrical resistance of mucus in the anterior vagina can be associated with oestrus in cattle. In a study of three cows, Metzger et al (1972) found that electrical resistance was lower at oestrus than during di-oestrus ($P<0.001$). Leidl and Stolla (1976) made a similar observation. Electrical resistance was well correlated ($r = 0.92-0.99$) with milk progesterone levels in Holstein cattle during the 4 days before and including oestrus (Heckmann et al, 1979). This agreed with Gartland et al (1976) and McCaughey and Patterson (1981). Foote et al (1979) inseminated 58 dairy cows on the basis of low probe readings and obtained a pregnancy rate of 52% versus 49% for 86 controls inseminated following the normal artificial insemination routine.

Vaginal smears

Symington and Hale (1967) stained mucus from the fornix area of the vagina of 5 zebu heifers with Leishman's stain. The preparations were examined microscopically (× 100). There was little variation in the cytological characteristics of the mucus throughout the oestrous cycle. In contrast, Cuq and Pessinabe (1979) reported that oestrus could be detected in zebu cattle using the differential staining properties of vaginal smears and the demonstration of cytoplasmic lipids (histochemistry) in vaginal smears or urinary sediments. They found the histochemical method to be more accurate and was therefore recommended since urine samples are easier to obtain.

Vaginal and body thermal conductance and temperature

Using a self-retaining heat-flow probe, Abrams et al (1973) measured the thermal conductance of the vagina of four Jersey and one Angus × Holstein

heifers 1 to 2 hours before and 4 to 5 hours after injecting 3 mg oestradiol-17β intravenously. There was an oestradiol-17β induced rise in vaginal thermal conductance that appeared to result from an increase in the rate of vaginal blood flow. This technique is not widely reported elsewhere.

Bane and Rajakoski (1961) reported observations by others that the average vaginal temperature of the cow increases gradually from the start of oestrus to a maximum after about 12 hours and then falls to the di-oestrus level.

Hurnik et al (1985), using infrared image display equipment, observed that the area enclosed by the 37°C isotherm on the gluteal region of 27 Holstein/Friesian cows tended to increase at the beginning of oestrus. The technique was, however, hampered by frequent false positives (33%) and inability to detect heat in 7% of the animals.

Ball et al (1978) measured rectal temperature of 10 cows each morning and milk temperature at morning and evening milking over 40 days, in order to determine the best time to inseminate, with or without standing oestrus. The best determination was based on the observation that milk temperature was at least 0.1°C higher during oestrus than before oestrus.

Vaginal pH

Zust (1966) and Schilling and Zust (1968) reported that cow intravaginal pH tends to decrease during oestrus. The pH was nearly constant during di-oestrus, ranging from 6.86 to 6.98 at the cervix, from 7.26 to 7.38 at the middle part and from 7.54 to 7.71 at the caudal part. The pH at the cervix decreased from 7.0 to 6.72 one day before oestrus, with a further decrease to 6.54 at the beginning of oestrus. The lowest pH (6.45) was recorded at the end of heat, immediately prior to ovulation.

3.2.3.3 Hormonal changes

Radio-immunoassay (RIA) and enzyme-linked immunosorbent assay (ELISA) enable prompt study of endocrine events. For example, the characteristic changes in blood or milk progesterone and other hormone levels can give an accurate indication of the time of oestrus (Hill et al, 1970; Dobson et al, 1975). Some ELISA techniques take as little as 5 minutes to yield results. However, samples must be taken frequently and this is impracticable under farm conditions. Moreover, the results may also require careful interpretation and, thus, adequate training of operators.

3.2.3.4 Laparascopic techniques

Many internal organs can be examined using the laparascope without causing extensive trauma (Wilson and Ferguson, 1984). The laparascope has been used to study the reproductive organs of many species, including cattle (Megale et al, 1956; Lamond and Holmes, 1965; Wishart and Snowball, 1973). Although the technique can be used to detect oestrus accurately (Ireland et al, 1980), it requires sophisticated equipment and training and is thus of little use to farmers and most field practitioners.

3.3 Gestation length, parturition and uterine involution

3.3.1 Gestation length

Gestation is the period from conception to parturition. Estimates of the gestation length among *Bos indicus* cattle average 285 days (Table 10),

Table 10. *Some estimates of the gestation period in* Bos indicus *cattle*

Breed	Location	Estimate (days)	Source
Zebu	Ethiopia	275	Glenn et al (1963)
Arsi	Ethiopia	276.2 ± 6.2	Swensson et al (1981)
Sahiwal	India	278.1–289.5	Sinha et al (1982)
Garre	Somalia	279	Aria and Cristofori (1980)
Zebu	Ethiopia	279.8 ± 1.7 to 281 ± 2.2	Azage Tegegn et al (1981)
Zebu	Cuba	281.5–287.7	Rodriguez et al (1983)
Zebu	Various	283–291	McDowell (1972)
Highland zebu	Ethiopia	283 ± 4.8	Mukasa-Mugerwa and Azage Tegegne (1989)
Kankrej	India	284 ± 5	Fulsounder et al (1984)
Dangi	India	284.7	Purbey and Sane (1978b)
Sahiwal	Somalia	285	Aria and Cristofori (1980)
West African Shorthorn	West Africa	285.3	Sada (1968)
Angoni	Zambia	285.9	NCSR (1970)
Angoni	Zambia	285.9 ± 13.2	Rakha et al (1971)
Kenana	Sudan	286 ± 0.2	Saeed et al (1987)
Red Sindhi	India	286.3	Ghose et al (1979)
Mashona	Zambia	286.5	NCSR (1970)
Zebu	Sudan	287	El-Amin (1976)
N'Dama	Ivory Coas	288.2	Ralambofilinga (1978)
N'Dama	West Africa	288.5	Sada (1968)
Gir	Brazil	289.7	Carregal (1975)
Sokoto Gudali	West Africa	290.5	Sada (1968)
Highland zebu	Ethiopia	291.0 ± 37.2	Alberro (1983)
Brahman	USA	292.8	Plasse et al (1968b)
Africander	Zambia	297.5	NCSR (1970)

which is within the range of 270–292 days reported for *Bos taurus* cattle (Andersen and Plum, 1965; Hunter, 1980; Bazer and First, 1983; Rodriguez et al, 1983). McDowell et al (1959) suggested that gestation tends to be longer in animals with a high proportion of zebu breeding.

Gestation length is largely determined by foetal factors, with some modification due to parity and maternal environment. Ordonez et al (1976) gave the heritability of gestation length in zebu cattle in Latin America

as 0.10, with a repeatability of 20%. Other estimates range from zero to 0.71 in taurine cattle, with most estimates between 0.25 and 0.50 (Andersen and Plum, 1965).

Egbunike and Togun (1980) noted a breed effect and Rodriguez et al (1983) observed that gestation averaged 281.5 ± 7.25 days in dairy cows, compared with 287.7 ± 9.23 days for beef cattle. Ordonez et al (1976) reported a significant effect of sire and dam of calf, sex of calf and year of calving and a significant sex of calf × parity interaction among zebu cattle in Venezuela. Bazer and First (1983) found that when embryos of short gestation breeds were transferred into dams of long gestation breeds, gestation was identical to the gestation average of the breed of the embryo, indicating the influence of the foetus on gestation length. This agrees with the findings of Sinha et al (1982), who calculated a gestation period average of 289 ± 3.2 days in Sahiwal cows bred with Sahiwal semen, compared with 278.08 ± 1.46 days in those bred with Jersey semen. Gestation was longer in cows carrying a crossbred male foetus (280.5 ± 1.85 days) than in those carrying a crossbred female foetus (277.0 ± 1.89 days), while the reverse was true for purebred foetuses (291.6 ± 4.6 days for females vs 286.0 ± 0.71 days for males). The observation that male calves are carried for 1 to 5 days longer than females has also been made elsewhere (Plasse et al, 1968b; Brito, 1973; Carregal, 1975; Chhabra and Goswami, 1980; Jainudeen and Hafez, 1980; Azage Tegegn et al, 1981; Chandramohan and Bhat, 1981; Khalafalla and Khalifa, 1983). These differences, however, tend not to be significant.

Gestation for twins tends to be 3 to 6 days shorter than for a single birth (Bazer and First, 1983) and heifers conceiving younger tend to have slightly shorter gestation periods (Hafez, 1980).

Lobo et al (1981) observed that, in Brazil, gestation length was significantly affected by year of calving but not genetic group (proportion of zebu blood), month of calving, parity or lactation length. El-Amin et al (1981), however, found a significant effect of month of calving in Red Butana cows in Sudan. Bartha (1971), working with Sahelian zebu cattle, and Carregal (1975), using Gir cows, failed to demonstrate significance due to season and Taylor et al (1984) found that season, calf sex, year of calving and dam parity were not important sources of variation in gestation length of Malvi cattle.

3.3.2 Parturition

Parturition is initiated by the foetus. This conclusion is based on the observation that defects in the foetal brain or adrenal gland prolong gestation in sheep, goats and cattle (Bazer and First, 1983).

The foetal pituitary releases adrenal-cortico-trophic hormone (ACTH) which stimulates the foetal adrenal gland to increase release of cortisol. In the cow, increases in foetal cortisol concentrations precede but parallel increases in oestrogen before delivery (Hunter et al, 1977). Foetal cortisol is therefore partly responsible for initiating parturition because it induces oestrogen synthesis in the placenta and elevated levels of prostaglandin $F_2\alpha$ ($PGF_2\alpha$), which results in the regression of the corpus luteum of pregnancy.

$PGF_2\alpha$ (or its analogues) causes abortion when administered during the first 120 days of pregnancy and induces delivery in 1 or 2 days when administered after 250 days. Between 120 and 250 days it appears to have very little effect (Schultz and Copeland, 1981), or the incidence of abortion is lower, probably due to extra-ovarian sources of progesterone. Similar effects can be achieved by administering glucocorticoids, which tend to

mimic foetal cortisol by altering placental steroid synthesis (Wagner, 1980). Long-acting glucocorticoids can be used between day 120 and day 250, while short-acting glucocorticoids are more effective from day 250 to day 280. Administering both glucocorticoids and prostaglandins, either simultaneously or 10 days apart, results in termination of pregnancy irrespective of the stage of gestation.

Parturition in cows often takes several hours (Bazer and First, 1983; Mukasa-Mugerwa and Mattoni, 1989). The first stage lasts 2 to 6 hours and the delivery stage about 30 to 40 minutes. The placenta is usually expelled 2 to 6 hours after delivery. Rao and Rao (1980a) calculated the average time for the expulsion of foetal membranes in Ongole cows and their crosses to be 5.16 ± 0.20 hours.

Delivery involves the coordinated rhythmic contraction of uterine smooth musculature, involuntary contraction of abdominal muscles and softening and dilation of the birth canal. Smooth muscle contractions are initiated by an increase in intracellular calcium under the influence of oxytocin and prostaglandins. Although relaxin is known to control the relaxation of the birth canal in swine, its exact role in cattle is not known.

Rao and Rao (1980a) calculated the mean weight of the membranes in Ongole cows to be 2.62 ± 0.08 kg, which is comparable to the 2.4 kg obtained by Mukasa-Mugerwa and Mattoni (1989) for Ethiopian Highland zebu. Foetal membranes were approximately 10–13% of calf weight and 0.66–1.0% of dam weight at parturition. On average, there were 91.56 ± 2.16 cotyledons per placenta; this is within the range of 70–142 noted for other cattle genotypes.

3.3.3 Uterine involution

Uterine involution in cattle takes 23 to 35 days (Dennis and Gachon, 1974) in two phases (Tennant et al, 1967; Donkin, 1980).

Bastidas et al (1984) found that uterine involution took an average of 33.0 ± 1.0 days in Brahman cows in Venezuela, and was influenced by month of calving ($P<0.01$) and cow age ($P<0.05$). Rao and Rao (1980b) estimated that, in Ongole cows, complete vulva involution took 20.2 ± 1.64 days, cervical involution 34.1 ± 2.61 days and involution of the gravid and non-gravid horns 28.20 ± 1.45 and 21.50 ± 1.23 days, respectively. Involution was more rapid in purebred Ongole cows than in those crossed with Jersey, Brown Swiss and Holsteins. Involution tends to be accelerated by walking.

Kadu and Kaikini (1976) calculated a significant correlation coefficient of 0.39 between the time taken for complete uterine involution and the interval from calving to first postpartum oestrus. This is important for reproductive management as it implies a link between postpartum ovarian activity and uterine contents and environment. In *Bos indicus* cattle, the duration of postpartum anoestrus is also affected by lactation and suckling. Maree et al (1974) observed, however, that calf presence did not significantly influence uterine involution time, as did El-Fadaly (1981) working on milked and suckled buffaloes in Egypt.

Involution rate is significantly affected by parity and month of calving (Bastidas et al, 1984). Involution among Brahman cows studied was slower during the dry season, but was not affected by suckling regime or calf birthweight. It was positively correlated ($r = 0.55$, $P<0.01$) with interval to postpartum follicle formation but negatively correlated with cow weight at calving ($r = -0.31$, $P<0.05$) and cervical involution ($r = -0.63$, $P<0.01$).

The regression rate (Y) was defined by the equation:

$$Y = 13.3 - 0.67X + 0.015X^2$$

where X is the diameter of the gravid horn. The equation accounted for 83% of the variation. Martinez et al (1982) found no important seasonal effect on uterine involution rate in zebu cows suckled twice daily. The overall average was 24.5 ± 8.74 days while complete absorption of the gestational corpus luteum was achieved after 27.83 ± 11.41 days.

3.4 Summary

Puberty can be defined as a qualitative or quantitative trait. Zebu heifers attain puberty later than taurine or taurine × zebu crosses. Puberty precedes sexual maturity and is influenced by the output of pituitary hormones and the size and activity of the gonads. Age and weight are the most important factors affecting the onset of puberty in heifers. Many heifers, particularly younger and lighter animals, exhibit non-pubertal oestrus.

Oestrous cycles last about 21 days in zebu cattle and the oestrous period lasts about 10 hours (range 2–18 hours). Oestrus is often subdued and affected by physiological and psychological factors. Almost a third of heats start at night which, with their short duration, implies that many may be missed.

Heat detection is primarily a management problem. Considerable skill is needed to detect oestrus from visible signs. Farmers who maintain good records and spend more time watching for heat will obtain better results. Many farmers in the tropics raise few cows and the main signs to look for are standing for mounting and/or mucus discharge. When animals can be aggregated, the use of teaser animals, with tail painting, chinball markers or marking web devices, offers the best aid to visual detection of oestrus. Hormonal assays, laparascopic examination and vaginal probes are very expensive and require extensive training, and offer little added advantage under field conditions.

The length of gestation in the zebu is about 285 days. It is primarily determined by foetal genetic factors, with some modification due to parity and sex of calf. Uterine involution is independent of factors such as season, suckling or calf birthweight following normal delivery.

3.5 References

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4. MEASURES OF REPRODUCTIVE PERFORMANCE

Fertility is the ability of male and female animals to produce viable germ cells, mate, conceive and deliver normal living young (Ensminger, 1969). The lifetime productivity of a cow is influenced by age at puberty (Chapter 3), age at first calving and calving interval.

This chapter presents data on age at first calving, calving rate, number of services per conception, calving interval and other measures that can be used to estimate cow productivity.

4.1 Age at first calving

First calving marks the beginning of a cow's productive life. Age at first calving is closely related to generation interval and, therefore, influences response to selection.

Under controlled breeding, heifers are usually mated when they are mature enough to withstand the stress of parturition and lactation. This increases the likelihood of early conception after parturition. In traditional production systems, however, breeding is often uncontrolled and heifers are bred at the first opportunity. This frequently results in longer subsequent calving intervals.

The average age at first calving in *Bos indicus* cattle is about 44 months (Table 11), compared with about 34 months in *Bos taurus* and *Bos indicus* × *Bos taurus* crosses in the tropics (Table 12).

Heritabilities of age at puberty, at first conception and at first calving are generally low (Table 13), indicating that these traits are highly influenced by environmental factors.

Jochle (1972) studied the effect of season on the reproductive performance of Brahman heifers that first conceived at between 15 and 37 months old in the Mexican Gulf coast. Of 111 heifers that first conceived at 15 to 24 months old, significantly more ($P<0.001$) did so during the dry season than during the wet season. However, among heifers that first conceived at more than 24 months old, most conceived during the rainy season and overall there was no significant difference between the percentage of heifers conceiving first during the rainy or dry season.

Oliveira (1974) observed that Nellore cows in Brazil that calved first in the dry season were younger than those that calved first in the rainy season. Miranda et al (1982a) found that age at first calving in Brazilian Nellore heifers was significantly affected by year and month of birth: calves born from January to May tended to be younger at first calving than those born between June and December. Sabino et al (1981) also found a year-of-birth effect among Haryana, Gir and another unspecified zebu type cattle in Venezuela, as did Sharma (1983) in Nagauri cattle in India. However, Sabino et al (1981) found that neither month of birth nor breed significantly affected age at first calving.

Table 11. *Some estimates of age at first calving in* Bos indicus *cattle*

Breed	Location	Estimate (months)	Source
Kenana	Sudan	23–58	Alim (1960)
Gobra	Senegal	31–40	Dennis and Thiongane (1978)
Boran	Kenya	34	Reinhardt (1978)
East African Zebu	Ethiopia	35.1 ± 3.1	Alberro (1983)
Red Sindhi	India	35.6	Basu et al (1979)
Sahiwal	India	35.8	Basu et al (1979)
Azaouak	Sahel	36–60	Bartha (1971)
InduBrazil	South America	36.8	Temblador and Sanchez (1977)
Brahman	Costa Rica	37–50	Bazan et al (1976)
Tharparkar	India	37.2	Basu et al (1979)
Various zebu	Brazil	37.5–50	Weitze (1984)
Sokoto Gudali	West Africa	38.6	Sada (1968)
N'Dama	West Africa	39.2	Sada (1968)
Nellore	Brazil	39.4 ± 0.02	Oliveira (1974)
White Fulani	Nigeria	40.4 ± 0.7	Oyedipe et al (1982)
Nganda	Uganda	42	Mahadevan and Marples (1961)
Zebu	Bangladesh	42–52	Mia and Ali (1974)
Haryana	India	42–56	Luktuke and Subramanian (1961)
East African Zebu	Uganda	43	Galukande et al (1962)
Butana	Sudan	44	Alim (1962)
Deshi	India	45	McDowell (1971)
Brahman	Mexico	45.9	Eversbusch (1978)
Gir and Zebu	Venezuela	47 ± 0.7	Sabino et al (1981)
Nagori	India	47.43 ± 1.06	Sharma 1983)
Sahiwal	Pakistan	48.8 ± 0.4	Ahmad and Ahmad (1974)
White Fulani	Nigeria	49.4	Knudsen and Sohael (1970)
Sudan Fulani	Mali	49.5	Wilson (1985)
Horro	Ethiopia	50	McDowell (1971)
Haryana	India	50 ± 0.5	Kumar and Bhat (1979)
Kenana	Sudan	50.1	Saeed et al (1987)
Fulani	Niger	50.2 ± 9.1	Wagenaar et al (1986)
Haryana	India	51	McDowell (1971)
Ankole	Uganda	51.3	Sacker and Trail (1966)
Zebu	Uganda	51.7	Sacker and Trail (1966)
Highland zebu	Ethiopia	53	Mukasa-Mugerwa et al (1989)
Non-descript	India	58.6 ± 1.0	Singh and Raut (1980)
White Fulani	Nigeria	60	Pullan (1979)

Table 12. *Some estimates of age at first calving among* Bos taurus *and* Bos taurus × Bos indicus *cattle in the tropics*

Breed	Location	Estimate (months)	Source
Jersey	India	27.5	Kumar (1969)
Jersey	Egypt	28.4	Khishin and El-Issawi (1954)
Jersey	Ceylon	30.0	Mahadevan (1956)
1/2 Jersey	Uganda	29.4	Kiwuwa and Redfern (1969)
1/2 Jersey	India	31.7	Kumar (1969)
1/2 Jersey	Rwanda	36.5	Compere (1963)
3/4 Jersey	Egypt	27.4	Khishin and El-Issawi (1954)
3/4 Jersey	India	39.5	Kumar (1969)
Ayrshire	Iraq	35.0	Asker et al (1966)
Friesian	Nigeria	29.0	Knudsen and Sohael (1970)
Friesian	India	30.1	Arora and Sharma (1980)
Friesian	Uganda	40.0	Trail and Marples (1968)
F_1 Friesian × zebu	Ethiopia	29.1	Alberro (1983)
1/2 Friesian	Nigeria	31.9	Knudsen and Sohael (1970)
3/4 Friesian	Nigeria	30.0	Knudsen and Sohael (1970)
Brown Swiss × zebu	India	37.2	Iype et al (1984)
Jamaica Hope	Jamaica	34.2	Wellington et al (1970)
Costeno	Colombia	39.5	Lemka et al (1973)
Blanco Orejine	Colombia	40.7	Lemka et al (1973)
Bos taurus × *Bos indicus*	Ethiopia	35.5–40.3	Galal et al (1981)
Boran × Charolais	Kenya	34.0	Gregory et al (1984)
Two breed cross	Various	33.8	McDowell (1985)
3/4 Cross	Various	44.5	McDowell (1985)
Bos taurus	Various	36.5	McDowell (1985)

Trail and Gregory (1981) found no significant difference in age at first calving ($P>0.05$) between Boran and Sahiwal heifers on a ranch in the Kenya Rift Valley, but Chhikara et al (1979) found that breed differences had a significant effect on age at first calving in Haryana, selected Haryana, Tharparkar and Sahiwal heifers in India. In an analysis of production data covering 14 years, Aroeria et al (1977) found that Gir heifers tended to be older than Nellore or InduBrazil heifers at first calving. Breed differences probably reflect differences in management conditions. The time taken by an animal to attain puberty and sexual maturity depends on the quality and quantity of feed available, which affects growth rate.

Wagenaar et al (1986) found a mean age at first calving of 50.2 ± 9.1 months in 146 Fulani-type dams in Niger. None of the factors tested for in the least squares analysis (herd, season and year of birth of dam, sex of the calf) significantly affected this parameter. However, Saeed et al (1987) found that year of birth significantly ($P<0.001$) affected age at first calving

Table 13. *Some estimates of heritability of age at puberty, age at first conception and age at first calving*

Cattle type	Estimate	Source
Age at puberty		
Haryana crosses	0.4 ± 0.21	Rathi (1979)
Age at first conception		
Zebu	0.14 ± 0.19	Bastidas and Verde (1981)
Guzerat	0.20	Baliero et al (1981a)
Age at first calving		
East African Zebu	0.08	Mahadevan and Marples (1961)
Guzerat	0.15 ± 0.18	Campos et al (1981)
Gir	0.15 ± 0.24	Campos et al (1981)
Sahiwal	0.20	Mahadevan et al (1962)
Gir	0.20 ± 0.11	Singh et al (1981)
Zebu	0.24 ± 0.30	Bastidas and Verde (1981)
Haryana	0.24 ± 0.02	Jegan and Tomar (1983)
Small East African Zebu	0.25	Galukande et al (1962)
Haryana	0.3 ± 0.27	Kumar and Bhat (1979)
Haryana crosses	0.36 ± 0.29	Rathi (1979)

in Kenana cattle in Sudan but that month of birth did not. Wagenaar et al (1986) observed a significant correlation ($P<0.001$, $r = -0.52$) between age at first calving and body weight at 3 years; heifers that weighed 10 kg more than average at 3 years old first calved 2 months earlier than average-weight heifers. There was no significant correlation between age at first calving and weight at 1, 2 or 4 years.

Dennis and Thiongane (1978) found that Gobra (Senegal Fulani) heifers kept on pasture and fed a balanced concentrate supplement calved first at 31 months old, compared with 40 months for unsupplemented heifers. El-Khidir et al (1979), working in Sudan, also found that improved nutrition significantly decreased age at first oestrus ($P<0.001$), which in turn reduced age at sexual maturity, first conception, calving and total rearing costs. Weitze (1984) found that supplemental feeding during the dry season reduced the average age at first calving from 45.0 to 37.5 months in Nellore, Gir and InduBrazil cattle in Brazil. Calving interval was also shortened by 52 days to 492 days (16.4 months), with a calving rate of 83%.

Singh et al (1982a) found age at first calving to be positively correlated with lactation milk yield and lactation length in Gangatiri cattle, as did El-Khidir et al (1979) and Singh et al (1981) working with Kenana and Indian-type cattle, respectively.

In general, earlier first calving increases lifetime productivity of cows. For example, Meaker et al (1980) showed that, despite lower first conception rates, Africander heifers calving first at 2 years old produced 0.6 more calves over their productive lifetime than those calving first at 3 years old, while Pinney et al (1962) estimated the increase to be 0.8 of a calf.

Meaker et al (1980) recorded heart girth, wither height, rump height, chest depth, body length, height and width, and hip width of beef cows until 6 years of age and found that only bodyweight at 2 years and wither

height at 3 years were affected by early calving. They concluded that animal growth up to 6 years is not significantly depressed by early calving.

Ahmad and Ahmad (1974) found that late first calving was associated with longer first dry periods (r = 0.29) and longer calving intervals (r = 0.36). Basu et al (1979) observed also that the number of services per conception increased with increasing age at first calving. Most data thus suggest that it is advantageous to breed heifers as early as is physiologically possible.

4.2 Fertility (calving) rates

4.2.1 Estimates

Fertility in cattle is affected by environmental, genetic, disease and management factors. These influence the reproductive process at ovulation, fertilisation or implantation or during gestation and parturition.

The commonest estimate of fertility rate is the percentage of mated or inseminated cows that become pregnant (pregnancy rate) or finally calve (calving rate). However, fertility can also be expressed in other ways. For example, Singh and Sharma (1984) referred to two measures of fertility: a general fertility rate, which is the ratio of calves born to females of breeding age, expressed as a percentage; and a specific fertility rate, which measures the number of births within a given group or the total fertility rates of females over their reproductive life. Net reproductive rate was given as the extent to which the female calves of one generation survive to reproduce themselves as they pass through calf-bearing age, expressed as the number of female calves that survive per 100 females of breeding age.

Fertility rates can also be estimated prior to calving as the percentage non-return rate. This is the number of cows bred that do not come back in heat and are thus assumed to have conceived. This value may be derived at 60, 90, 120, 145 or 200 days after mating (McDowell et al, 1976). Where artificial insemination is employed, fertility rates can be expressed as the number of calves born per 100 inseminations (Macfarlane and Goodchild, 1973). Progesterone assay now makes it possible to determine conception rates as early as 21 days after breeding. It is also ideal for estimating the magnitude of early embryonic losses.

Fertility rates in zebu cattle are generally low, particularly in animals raised traditionally (Table 14) under less-than-ideal management. For example, Rennie et al (1976) estimated the calving rate of traditionally raised Tswana cattle in Botswana as 46.4%, compared with 74.0% for similar animals on a ranch. The higher calving rate on the ranch was probably due to the animals being better fed and managed than those under traditional management. Nuru and Dennis (1976) calculated a calving rate of 67% for White Fulani cattle raised on government ranches in Nigeria, compared with about 34–55% for similar animals raised by local herders. Trail et al (1971) reported a conception rate of 79% in Ankole, Boran and an unspecified zebu-type cattle in western Uganda where feed and water were abundant and diseases were controlled.

De Vaccaro et al (1977) studied reproductive performance in a herd of Nellore cattle in the Amazon over six mating seasons from 1968 to 1973. No animals were culled for reproductive reasons. Calves were weaned at 250 days old and breeding was between October and December each year. Overall calving rate was 59% (Table 15). The authors suggested that the low

Table 14. *Some estimates of fertility (calving) rates among some* Bos indicus *cattle in the tropics*

Breed	Location	Estimates (%)	Source
		Traditional management	
Nellore	Brazil	20–66.6	Fonseca et al (1981)
Fulani	Nigeria	34.2–54.5	Nuru and Dennis (1976)
Fulani	Nigeria	36	Pullan (1979)
Native zebu	Botswana	36.2–51.9	Reed et al (1974)
Southern Darfur	Sudan	40.0	Wilson and Clarke (1976)
Guzerat	South America	42.2–100	Pires et al (1977)
Highland zebu	Ethiopia	46	Mukasa-Mugerwa et al (1989)
Tswana	Botswana	46.4	Rennie et al (1976)
Zebu	Malawi	52–69	Butterworth and McNitt (1984)
		Ranch/research station/migratory or improved pasture management	
Guzerat	Central America	32.5	Texeira Viana and Jondet (1978)
Nellore	Central America	45.3	Texeira Viana and Jondet (1978)
Boran	Tanzania	53–73	Macfarlane and Goodchild (1973)
Africander	Zambia	54.2	Thorpe et al (1981)
Native zebu	Zambia	57.6	Thorpe et al (1981)
Nellore	Brazil	58.3–84.7	Fonseca et al (1981)
Azaouak	Sahel	58.8	Bartha (1971)
Nellore	Peru	59	de Vaccaro et al (1977)
Dangi	India	60.5	Purbey and Sane (1981)
Zebu	Cuba	61.18	Ronda et al (1981)
Brahman	Costa Rica	62.8–81.7	Bazan et al (1976)
Southern Darfur	Sudan	65.0	Wilson and Clarke (1976)
Boran	Zambia	66.0	Thorpe et al (1981)
Fulani	Nigeria	67	Nuru and Dennis (1976)
Zebu	Botswana	69–82	Buck et al (1976)
Angoni	Zambia	69.1	Thorpe et al (1981)
Zebu	Panama	72.1–90.6	Espaillat et al (1979)
Tswana	Botswana	74.0	Rennie et al (1976)
Brahman	Mexico	75	Linares et al (1974)
Boran	Zambia	75.4	Thorpe and Cruickshank (1980)
Zebu	Sudan	77.0	El-Amin (1976)
Various zebu	Uganda	79.0	Trail et al (1971)
Angoni	Zambia	82.5	Thorpe and Cruickshank (1980)
Brahman	Mexico	85.5	Eversbusch (1978)

Table 15. *Calving rates of Nellore cattle after successive mating opportunities*

Mating opportunity	Number of females exposed	Percentage of females calving for the						Overall calving rate (%)
		1st	2nd	3rd	4th	5th	time	
1	925	64						64
2	700	26	23					49
3	654	6	42	12				60
4	374	3	27	22	7			59
5	195	2	18	33	10	0		63
6	28	–	10	10	18	0		38
Total	2876							59

Source: de Vaccaro et al (1977).

calving rate after the sixth mating opportunity (38%) was due to the small number of cows presented for breeding, but it may also have been age-related. At this time, most cows would have been 9 to 10 years old, and fertility commonly decreases in cows of this age in the tropics. Cows calved irregularly and 33% of those bred for the fifth time gave birth to only their third calf and 18% to their second. In addition, several cows calved for the first time after the third, fourth or even fifth breeding opportunity. Although such cows would have been culled in a commercial livestock enterprise, traditional smallholders usually have only one or a few cows and cannot afford to cull extensively for infertility. Many keep their animals for long periods in the hope of eventually getting a calf. This practice is unsatisfactory because scarce feed resources are used by unproductive animals.

4.2.2 Effects of age and lactation

Analysing data from Botswana, Buck et al (1976) found that fertility rate increased from 69% in 2.5-year-old cows to a maximum of 82% in 6- to 7-year-old cows and then declined. In Bolivia, Plasse et al (1975) also recorded an increase in pregnancy rate from 50% in 3-year-old purebred Criollo and Criollo × zebu crossbreds to 75% in 7-year-olds. Fertility then declined to 50% among 12-year-olds. Causes of these age-related differences include lactational stress in young growing animals and the ability of older cows to gain bodyweight and condition quickly after calving.

Lactation has a negative effect on cow bodyweight and thus indirectly affects animal reproduction. Trail et al (1971) and Topps (1977), for example, observed that cows grazing medium- or low-quality forage used body reserves to maintain milk yield in response to suckling. Such animals should be supplemented during lactation to increase their conception rates (Warnick, 1976; Topps, 1977).

In a study by Reynolds et al (1979) involving Angus, zebu and zebu-cross cattle in which all heifers were bred at 2 years, heifers had a 6.8% lower pregnancy rate after 2 services ($P<0.05$) and became pregnant 4.2 days later ($P<0.01$) than older cows. Three-year-old lactating animals also showed a 10.9% lower pregnancy rate than older lactating cows ($P<0.01$), which suggests that lactation has a greater effect on postpartum anoestrus in

young primiparous animals than in older cows. Bastidas et al (1984) confirmed this in Brahman first-calf cows: continuous suckling significantly reduced pregnancy rate compared to suckling twice daily (46.3 ± 0.08 vs 79.8 ± 0.08%).

4.2.3 Effect of breed

One of the few studies reporting extensively on the effect of breed on fertility in Africa was undertaken by Thorpe and Cruickshank (1980) in Zambia. They found that conception rate (averaging 82.5, 78.1 and 75.4% among 675 Angoni, 731 Barotse and 815 Boran cows, respectively) was significantly affected by year but not sire breed, although conception rate was higher in Angoni and Barotse cows when mated to bulls of their own breed. Evidence for dam breeds was also not conclusive. Among the Barotse, dry heifers had higher conception rates than lactating cows, whereas lactating Angoni and Boran cows had higher conception rates than dry cows. Perhaps the most significant observation among the Angoni and Barotse (but not the Boran) was that cows that calved early in the calving season were more likely to conceive during the following mating season than cows that calved late. This was consistent with observations by Trail et al (1971) on Ankole and Boran cows in Uganda, and by Buck et al (1976) on zebu cattle in Botswana.

4.2.4 Effect of bodyweight

Thorpe and Cruickshank (1980) observed that Barotse, Angoni and Boran cows that calved were marginally heavier at the beginning and end of the breeding season than cows that did not calve. This was consistent with the findings of Buck et al (1976) and Buck and Light (1982) in Africander, Tswana and Tuli cattle and de Vaccaro et al (1977) in Nellore cattle. The last authors calculated that heifers calving at the first and second opportunity averaged 272 ± 33 kg liveweight, compared with 262 ± 27 kg ($P<0.01$) for those failing to calve. Ward and Tiffin (1975) also emphasised the importance of cow bodyweight at time of breeding: Mashona cows that weighed 318–364 kg at mating had a calving rate of 87.5%, compared with 45% for cows weighing 237–273 kg.

4.2.5 Effects of year and season

Thorpe and Cruickshank (1980) attributed the significant effect of year on calving rate to differences between years in the quantity and quality of forage available. Bishop (1978) found that calving percentage of Africander cross cows in South Africa was positively correlated ($r = 0.84$, $P<0.05$) with rainfall in the previous year, as did Butterworth (1983) in an analysis of 18 272 births from Nguni cattle in Swaziland. Monthly calving frequency was correlated with previous monthly rainfall records but most of the variation was accounted for by rainfall 10 months earlier in both the highveld (79%) and middleveld (50%). Jochle (1972) also found direct linear correlations between conception rate in Brahman cows and precipitation, pressure and temperature (Table 16). These findings further emphasise the importance of nutritional effects on fertility (see Chapter 6).

4.2.6 Genetic effects

Heritability of fertility rate is low. It was estimated as 0.14 ± 0.19 by Bastidas and Verde (1981) in Venezuela, while Cruz et al (1976) obtained

Table 16. *Linear correlations between the seasonal reproductive performance of Brahman cows and climatic factors*

Variables	2	3	4	5
1. Conception	0.643	−0.751	0.827	0.324
2. Precipitation	–	−0.668	0.718	0.225
3. Pressure		–	−0.918	0.390
4. Temperature			–	0.161
5. Humidity				–

Source: Jochle (1972).

values of 0.25 and 0.15 for conception rate, and 0.09 and 0.11 for calving rate in Brahman heifers and older cows, respectively. Conception rates often exhibit substantial heterosis after crossbreeding (see section 4.7).

Sengupta (1975) found a relationship between fertility rates and blood groups in 645 Haryana cows randomly mated over 4 years. Cows with AA blood group had a significantly higher conception rate (67%) than cows with AB (47.5%) and BB (51.1%) blood type. Type AA cows calved significantly earlier (41.2 months) than either the AB (44.5 months) or BB (44.7 months) animals. It would be useful to investigate this further in animals from different populations, to find out if the phenomenon could be of use in identifying animals with higher inherent fertility.

4.3 Number of services per conception

The number of services per conception (NSC) depends largely on the breeding system used. It is higher under uncontrolled natural breeding and low where hand-mating or artificial insemination is used. A range of values for NSC is presented in Table 17 NSC values greater than 2.0 should be regarded as poor, and some of the factors contributing to high NSC values are elaborated below.

Choudhuri et al (1984) estimated the repeatability of NSC to be 19% from 2152 records for Haryana cattle. The NSC was 2.81 ± 0.03 and was

Table 17. *Some estimates of the average number of services per conception (NSC)*

Breed	Location	Estimates (NSC)	Source
InduBrazil	South America	1.4–1.6	Temblador and Sanchez (1977)
Nagori	India	1.5 ± 0.4	Sharma (1983)
Dangi	India	1.65	Purbey and Sane (1981)
Zebu	Ethiopia	1.74–1.8	Azage Tegegn et al (1981)
East African Zebu	Ethiopia	2.0 ± 1.2	Alberro (1983)
Haryana	India	2.1–2.7	Kumar and Bhat (1979)
Various	India	2.1–3.6	Qureshi (1979)
Arsi	Ethiopia	2.4–2.6	Swensson et al (1981)
Haryana	India	2.8	Choudhuri et al (1984)

significantly affected by herd, season, placenta expulsion time, lactation length and milk yield. Since heritability can be broadly estimated from repeatability, this study indicates that heritability of NSC is low and most of the variation in NSC is attributable to environmental factors.

Sharma and Bhatnagar (1975) found a significant effect of parity on NSC in Sahiwal, Red Sindhi and Tharparkar cattle. The NSC was highest at the fourth lactation for F_1 crosses with Brown Swiss. Kumar and Bhat (1979) noted that Haryana heifers needed more services per conception than cows.

Azage Tegegn et al (1981), using 3 local Ethiopian breeds, the Barca, Horro and Boran, found that NSC was lower for animals from wet areas than for those from drier areas (1.74 ± 0.6 vs 1.98 ± 0.07). Crossbred cows required 0.12 and 0.14 fewer services per conception than local zebu cows in wet and dry areas, respectively.

El-Amin et al (1981) concluded that NSC did not differ significantly between Red Butana and Red Butana crosses (average 2.6) but was influenced by month of calving. NSC increased over the study period, probably due to changes in management. This is partly supported by an analysis by Busch and Furstenberg (1984) of 483 600 inseminations performed by 379 technicians on 623 farms in the USA, which showed that the 90- and 120-day non-return rate differed significantly among inseminators and the inseminator effect was greater than the farm effect. However, non-return rate did not differ among bulls.

4.4 Calving interval

Calving interval can be divided into three periods: gestation, postpartum anoestrus (from calving to first oestrus) and the service period (first postpartum oestrus to conception) (see Figure 12). Factors affecting gestation length were reviewed in Chapter 3. The following section therefore relates to factors that influence the length of the postpartum anoestrous and service periods. This is sometimes also called the "days open" period and is the part of the calving interval that can be shortened by improved herd management.

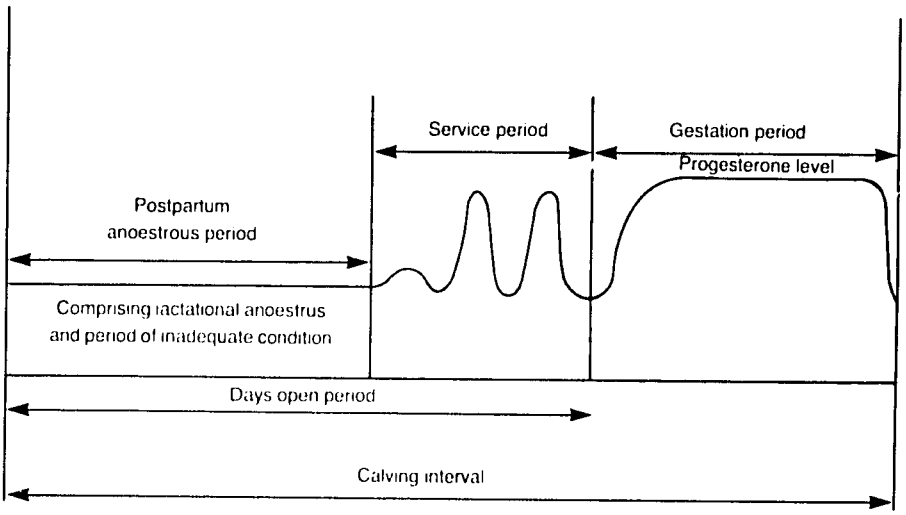
The "days open" period should not exceed 80–85 days if a calving interval of 12 months is to be achieved (Peters, 1984). This requires re-establishment of ovarian activity soon after calving and high conception rates. The duration of this period is influenced by nutrition (Wiltbank et al, 1962), season, milk yield, parity (Buck et al, 1975), suckling and uterine involution. At any time, the effects of one or more of these factors may be confounded.

Calving interval has been extensively analysed and reported. It is probably the best index of a cattle herd's reproductive efficiency. Resumption of ovarian activity in the postpartum period does not necessarily lead to conception and methods of stimulating oestrus must be considered in relation to their effect on conception (Holness et al, 1980) and, indirectly, calving intervals. The estimates of the duration of the various phases of the calving interval shown in Figure 12 are based on averages in the literature for cows raised under traditional management.

4.4.1 Estimates

Pullan (1979) quoted previous work in which it was estimated that only about 4% of Nigerian zebu cattle calved each year, 22% calved every other

Figure 12. *Schematic representation of the relationship of progesterone levels to the calving interval and its main components*



year and 73% calved irregularly. Sada (1968) suggested that, in N'Dama, Sokoto Gudali and West African Shorthorn cows, calving intervals shorter than 410 days (13.6 months) are very good, those of 411–460 (13.6–15.3 months) are satisfactory and those greater than 461 days (15.3 months) are unsatisfactory.

Estimates of calving interval in zebu cattle range from 12.2 to 26.6 months (Table 18). By Sada's (1968) standards, many of the calving intervals given in Table 18 are unsatisfactory. Most of the longer calving intervals were from traditionally raised animals.

4.4.2 Genetic effects

Borsotti et al (1976) observed that genotype had a significant effect on the calving interval of Brahman cows in Venezuela. In Mexico, Valesio (1983) found calving intervals of 18.1 months for Gir and InduBrazil cattle, 18.8 months for Brown Swiss × zebu crosses and 20.3 months for pure Brown Swiss cattle. The long calving interval of the Brown Swiss probably reflects lack of adaptation to the humid environment. Nodot et al (1981) reported that calving interval was affected by maternal grand sire. However, Duarte et al (1983) found no significant effect of genetic grouping (proportion of zebu blood) among cows in Brazil.

Estimates of the repeatability of calving interval range from near zero to 0.37 (Table 19). Heritability estimates range from 0.003 to 0.33 (Table 20). The heritability values of 0.68 ± 0.14 obtained by Parmar and Johar (1982) in Tharparkar cows in India, and 0.81 to 0.86 found by Weitze (1984) among Nellore cows in Brazil, appear to be exceptionally high.

4.4.3 Effects of year and season

Year effects on calving interval have been reported by Choudhuri et al (1984) in Haryana cows in West Bengal, India, Hinojosa et al (1980) in unspecified zebu cattle in Mexico, Miranda et al (1982b) in Nellore cows in Brazil, Alim (1960) in Kenana cows in India and Borsotti et al (1976) in Brahman cattle in Venezuela.

Table 18. *Some estimates of calving interval in zebu cattle*

Breed	Location	Estimate (months)	Source
Horro	Ethiopia	12.2	McDowell (1971)
Arsi	Ethiopia	12.9–15.1	Swensson et al (1981)
Kenana	Sudan	13.2	Alim (1960)
Native	India	13.5	Hedge et al (1978)
Ankole	Rwanda	13.5–17.1	Furnemont (1981)
Brahman	USA	13.6 ± 0.1	Plasse et al (1968)
Sahiwal	Kenya	13.7	Kimenye (1981)
Deshi	India	13.7 ± 5.9	Moulick et al (1971)
Brahman	Venezuela	13.8–18.9	Borsotti et al (1979)
Africander	Zambia	14.1	NCSR (1970)
Nellore	Brazil	14.1 ± 0.1	Oliveira (1974)
White Fulani	Nigeria	14.2–18	Oyedipe et al (1982)
Zebu	Brazil	14.4 ± 3.4	Duarte et al (1983)
Nellore	South America	14.7–15.6	Miranda et al (1982b)
Brahman	Mexico	15.1	Eversbusch (1978)
Haryana	India	15.6	Kumar (1982)
Zebu	India	15.8	Ngere (1970)
Haryana	India	15.9 ± 3.9	Lemka et al (1973)
Brahman	Costa Rica	16 ± 6	Bazan et al (1976)
Haryana	India	16.1	McDowell (1971)
Gir	Venezuela	17.9 ± 0.71	Montoni et al (1981)
Zebu	Malawi	18	Butterworth and McNitt (1984)
Gir and InduBrazil	Mexico	18.1	Valesio (1983)
Fulani	Niger	19.6 ± 5.1	Wagenaar et al (1986)
Gir	India	20.1	Malik and Ghei (1977)
Fulani	Mali	22.1 ± 6.7	Wilson (1985)
Native	India	23.3	Kartha (1934)
Highland zebu	Ethiopia	25	Mukasa-Mugerwa et al (1989)
Native	Rwanda	26.6	Compere (1960)

Oliveira (1974), working with Nellore cattle, observed that animals calving in the dry season had an average subsequent calving interval of 13.9 months, compared with 14.5 months for those that calved in the wet season. Oyedipe et al (1982), working with White Fulani heifers, found calving intervals of 15.3 and 18 months for the dry and wet seasons, respectively. The authors suggested that the difference was due to the fact that cows calving in the dry season could take advantage of improved nutritional conditions during the subsequent rainy season to meet their total requirements for maintenance, growth and lactation. In addition, a larger proportion of dry-season calves die due to inadequate nutrition. Both

Table 19. *Some estimates of repeatability of calving interval*

Breed type	Estimate	Source
Zebu	0.022	Hinojosa et al (1980)
Brahman	0.05–0.50	Borsotti et al (1979)
Butana	0.111 ± 0.039	Alim (1962)
Deoni	0.20	Deshpande and Singh (1977)
Deshi	0.21	Moulick et al (1971)
Kenana	0.23 ± 0.031	Saeed et al (1987)
Haryana	0.24	Choudhuri et al (1984)
Haryana	0.27	Dhoke and Johar (1977)
Malvi	0.29 ± 0.02	Singh et al (1983)
Brahman	0.32	Borsotti et al (1976)
Gir	0.37	Singh et al (1982b)

Table 20. *Some estimates of heritability of calving interval*

Breed type	Estimate	Source
Haryana	0.003–0.33	Dhoke and Johar (1977)
Nellore	0.022	Miranda et al (1982b)
Deshi	0.09	Moulick et al (1971)
InduBrazil	0.10 ± 0.08	Nodot et al (1981)
Gir	0.22 ± 0.11	Singh et al (1982b)
Guzerat	0.24	Baliero et al (1981b)

factors lead to earlier re-establishment of oestrus in cows that calve in the dry season. These suggestions were supported by Landais et al (1980), who found that cows calving in October in Côte d'Ivoire usually conceived again in the following January, while those calving in January were unlikely to conceive during the subsequent mating period. Early death of calves also reduced calving interval by more than 2 months and abortion shortened it by several days. The calving interval for cows whose calves died prior to fertile mating was estimated by the formula: CI = 328.3 + (0.992 × age of the calf at the time of death) days. A similar estimate by Wilson (1985) among Sudanese Fulani cattle in Mali yielded a prediction equation of CI = 499.5 + (0.318 × age at calf death) days.

Although these observations involved cows that aborted or lost their calves, they indicate that calf rearing strategies, such as early weaning, bucket feeding or partial suckling, can influence subsequent dam reproduction. For example, Wells et al (1986) found that partial suckling in Africander cows significantly ($P<0.01$) reduced the number of cows that were anovulatory for 100 days postpartum and increased conception rates ($P< 0.001$). Partial suckling reduced the interval from parturition to first ovulation by 20 days and the mean interval to conception by 21 days averaged over all cows. In a study of 6- to 10-year-old Bunaji cows, Eduvie and Dawuda (1986) found that the interval from calving to conception averaged 232.5 and 72.6 days for suckled and non-suckled animals, respectively. The associated calving intervals were 512.5 and 352.6 days

with 60–90 day pregnancy rates of 21.1% and 72.7%, respectively. Serum progesterone levels showed that suckling interfered with ovarian activity and thus conception during the postpartum period, resulting in a prolonged calving interval.

4.4.4 Effect of nutrition

Underfeeding delays puberty in taurine heifers (Joubert, 1954a) and stops oestrus and ovarian activity in heifers that are already cycling (Bond et al, 1958; Terqui et al, 1982). Wiltbank et al (1962) demonstrated the same effect in mature Hereford cows. The cows were fed a high- or a low-energy ration before calving; half of the animals in each group were then fed a high- or low-energy ration after calving. The resulting pregnancy rates were 95, 77, 95 and 20% on the high-high, high-low, low- high and low-low ration, respectively. These results, which agree with those of Joubert (1954b), indicate that level of feeding after calving has a greater effect on subsequent pregnancy than level of feeding before calving. The high level of feeding after calving shortened the interval from first breeding to conception and thus reduced calving interval. In zebu cattle, Mukasa-Mugerwa et al (1989) found a calving interval of 780 days (26 months) in traditionally raised Ethiopian highland zebus. Lactation length was 239 days (8 months). Cows thus failed to conceive for more than 8 months after lactation had ceased. This may be the average period required to gain sufficient bodyweight and condition to start cycling and conceive again, given the limited nutritional resources of the traditional system.

Calving intervals also tend to be shorter in animals that are more productive in other respects. This may be a reflection of the effect of nutrition, since more productive animals are usually fed better than unproductive animals. For example, Baliero et al (1981b) found that the calving interval of Guzerat dairy cows decreased by 17.8 days for every 1000 kg increase in lactation milk yield. Dutt et al (1974) found a positive correlation ($r = 0.33-0.60$) between lactation length and calving interval in Tharparkar cows in Uttar Pradesh, as did Choudhuri et al (1984) in Haryana cattle and Singh et al (1982b) in Gir cows. Dutt et al (1974) found a higher correlation (0.67) between calving interval and the duration of the service period among Tharparkar cattle. However, Duarte et al (1983) did not find a correlation between length of lactation and calving interval in zebu cattle in Brazil.

Plasse et al (1968) found that dam age at calving, sex of calf and location all significantly ($P < 0.01$) affected calving interval in Brahman cows. The location × age interaction was also significant ($P < 0.05$). The differences due to location seemed to arise from differences in the length of the breeding season. In a study of 5356 Brahman cows in Costa Rica, Bazan et al (1976) also found herd and district to have a significant effect on calving interval as did Choudhuri et al (1984) in 2152 Haryana cattle in West Bengal, India.

4.4.5 Effect of age

In zebu cattle, calving interval is longest in first-calf heifers and older cows, and shortest in cows of intermediate age (6–9 years old).

Plasse et al (1972) reported a maximum calving interval of 496 days in 12- to 16-year-old cows, with similar values for young cows 3–6 years old. Calving interval was shortest (424 days) in cows of intermediate age (6–

9 years old). Earlier, Plasse et al (1968) had also observed a tendency for calving intervals to shorten with increasing age in Brahman cows, as did Hinojosa et al (1980) in a commercial zebu herd in Mexico.

In an analysis of data collected over 20 years on zebu cattle in Venezuela, Montoni et al (1981) found that calving interval was longest between the first and second calving, and shortest between the fifth and sixth calving. Velarde et al (1975), working with Brahman cattle in Costa Rica, also found the longest calving interval between the first and second calving, and the shortest between the fourth and fifth calving. These observations were consistent with those of Miranda et al (1982b), working with Nellore cattle in Brazil, Baliero et al (1981b), who studied Guzerat cows, and Dhoke and Johar (1977), working on Haryana cows in India. The last authors found that calving interval continued to shorten until after the sixth parity. This was also observed by Kumar and Bhat (1979), Ram and Balaine (1979), Oyedipe et al (1982), Duarte et al (1983) and Singh et al (1983). De Vaccaro et al (1977) noted that the first calving interval was considerably longer than the second or third interval in Nellore cattle in Peru: only 14.5% of the intervals lasted less than 400 days (13.3 months) and 49.5% exceeded 601 days (20.0 months) (Table 21).

Table 21. *Calving interval patterns of Nellore cattle in Peru*

Interval no	n	Mean ± SD (days)	Percentage of intervals of various (days)							
			<300	300-400	401-500	501-600	601-700	701-800	801-900	901-1000
1	584	614 ± 157	0.5	11	15	17	19	31	5	1.5
2	242	495 ± 187	–	20	25	18	19	13	4	2
3	60	464 ± 141	1	25	27	18	28	–	–	–
Total	886	571 ± 168	0.5	14	19	17	20	24	4	1.5

Source: de Vaccaro et al (1977).

4.4.6 Other factors

Calving interval can be influenced by the sex of the calf (Plasse et al, 1968). In a study of zebu cows in Kenya, Reinhardt (1978) observed that cows with male calves had a longer calving interval than those with female calves (430 vs 383 days). Subsequently, Reinhardt and Reinhardt (1981) found that dams stopped suckling, and therefore weaned, female calves earlier than males (8.8 vs 11.5 months). Montoni et al (1981) noted that cows with male calves had a calving interval 19.1 days longer than that of cows with female calves. Wilson (1985) calculated 29 days more.

Calving interval may be influenced by placenta expulsion time (Choudhuri et al, 1984) and uterine pathology. Hinojosa et al (1980) found a favourable mean calving interval of 383 ± 3.7 days (12.8 months) in a well-managed herd in Mexico. They attributed the shortness of the calving interval to the absence of brucellosis, which reduced abortion rate, and stringent culling of infertile cows.

4.5 Specific measures of cow productivity

4.5.1 Cow efficiency

The productive efficiency of cows can be described in biological or economical terms. Biological efficiency is usually measured in terms of calf weight weaned per cow exposed per total digestible nutrients consumed, because this indirectly accounts for milk production, nutrition and reproduction (Ritchie, 1984).

Totusek (1984) suggested the following equation for economic efficiency:

profit = weaning weight × percent calf crop × selling price per pound of calf × number of cows – annual cost of cow-calf operation

In each case cow reproductive performance (fertility) is very important. Richardson et al (1975) estimated that 70% of the variability in cow productivity is attributable to calving rate.

4.5.2 Cow productivity index

Cow productivity index incorporates calf bodyweight at 6, 9 or 12 months and the bodyweight equivalent of milk produced. As used by Trail and Gregory (1981), measures of reproductive performance, cow and calf viability, milk yield, growth and cow weight are combined to derive the cow productivity index (kg) per cow per year or per 100 kg liveweight of cow of breeding age maintained annually. It is computed as:

(cow viability (%) × calving percentage × calf viability (%) × calf weight at 6, 9 or 12 months or at weaning (kg)) + (cow viability (%) × calving percentage × lactation milked-out yield (kg))/9.

This index may also be expressed as a ratio of cow body weight or estimated metabolic weight.

4.5.3 Most probable producing ability

Most probable producing ability (MPPA) allows dams with different numbers of records for a given trait to be compared within a herd. It is estimated as[1]:

$$\text{MPPA} = \overline{H} + \frac{NR}{1 + (N-1)R}(\overline{C} - \overline{H})$$

Where:

$\overline{H}$ = herd average, always 100

N = number of calvings or parturition records per dam

R = repeatability of the trait

$\overline{C}$ = average value for the trait for all young produced by the dam (Lasley, 1972).

[1] J S Brinks, Colorado State University, Fort Collins, Colorado, USA, personal communication.

4.5.4 Expected progeny difference

Expected progeny difference (EPD) uses information on sire performance as well as information from progeny and other relatives to account for

non-random mating and genetic trends. The method produces EPDs for dams as well as sires.[2]

EPDs are determined for different traits simultaneously. An EPD for a particular trait is based not only on data for that trait but also on data for other traits. An example of how EPDs can be used is given in the 1986 Sire Summary of the American Gelbvieh Association.[3]

[2] J S Brinks, Colorado State University, Fort Collins, Colorado, USA, personal communication.

[3] American Gelbvieh Association, 5001 National Western Drive, Denver, Colorado 80216, USA.

4.5.5 Lactation index

Narain and Chand (1980) proposed a lactation index for dairy cows, in which productivity is assessed by combining linearly four economically important traits such that variation between animals is maximised relative to that within. Data on lactation yield (X_1), lactation length (X_2), calving interval (X_3) and dry period (X_4) are required.

Productivity data from Sahiwal and Haryana cattle at the Merut and Agra military farms in India were used to obtain correction factors for converting subsequent lactation records to the first. The following indices were obtained.

Sahiwal cattle $Y = X_1 - 6.8\,X_2 + 7.43X_3 - 7.33X_4$

Haryana cattle $Y = X_1 - 1.92X_2 + 2.47X_3 - 2.00X_4$

The indices were not, however, highly repeatable.

4.5.6 Breeding efficiency

Spielman and Jones (1939) indicated that fertility in dairy cows depends on the frequency of reproduction and the total number of successful gestations. They obtained a significant correlation of 0.804 ± 0.026 between reproductive efficiency measured in terms of calving intervals and longevity in terms of number of established pregnancies. Wilcox et al (1957) subsequently applied the principle using the formula:

$$\text{Breeding efficiency} = \frac{365 \times (N-1) \times 100}{D}$$

Where: N = total number of parturitions
D = days from first to last parturition.

4.6 Cow productivity and useful life

Although zebu cattle tend to reach sexual maturity rather late, their productive life and that of their crosses tends to be longer than that of taurine cattle (Fowler, 1969).

The useful life of zebu cattle in the tropics varies from 4.5 to 8.5 years, during which cows give 3 to 5.4 calves (Alim, 1960, 1962; Aroeria et al, 1977; Pires et al, 1977; Saeed et al, 1987; Mukasa-Mugerwa et al, 1989). Wagenaar et al (1986) estimated that the average number of parturitions among Fulani cattle in Niger was 5.1, including abortions.

Basu et al (1983) estimated the heritability of herd life as 0.69 ± 0.10. If animals with long productive life are also highly productive in other respects, it is advantageous to keep them in the herd as long as possible (Saeed et al, 1987). This might, however, increase the generation interval and thus reduce the response to selection. The trade-off between immediate productivity and herd improvement must, therefore, be carefully considered.

4.7 Effect of inbreeding and heterosis on reproduction

Khanna et al (1980) studied the effects of inbreeding on Haryana and Sahiwal cattle (Table 22). Inbreeding (coefficient 6.96%) increased age at first calving but shortened service period and calving interval in Haryana cattle. At a higher inbreeding level of 14.03%, Sahiwal cattle were older at first calving and had longer service periods and calving intervals than non-inbred cows.

Table 22. *Effect of inbreeding on reproductive characteristics of Haryana and Sahiwal cattle*

	Haryana		Sahiwal	
	Non-inbred	Inbred	Non-inbred	Inbred
Average inbreeding (%)	–	6.96	–	14.03
Age at first calving (days)	1636 ± 19	1712 ± 32	1420 ± 20	1441 ± 30
Service period (days)	241 ± 4	205 ± 9	209 ± 8	222 ± 16
Calving interval (days)	522 ± 4	490 ± 4	463 ± 10	528 ± 22

Source: Khanna et al (1980).

Odedra et al (1977) found little effect of inbreeding on Gir cattle production over a range of inbreeding coefficients from less than 6.25% to greater than 12.5%. However, first calving interval was markedly longer at an inbreeding level of 12.5% or more and the first dry period was longer in highly inbred animals (Table 23).

Table 23. *Effect of inbreeding on production and reproductive characteristics of Gir cattle*

	Inbreeding level (%)			
	<6.25	6.25–12.40	12.5	>12.5
Age at first calving (days)	1715.00	1829.20	1807.00	1672.00
1st lactation yield	1577.64	1811.69	1521.00	1792.40
1st lactation length (days)	309.20	376.00	370.00	332.50
1st dry period (days)	164.58	125.31	167.24	282.10
1st calving interval (days)	491.90	491.80	537.30	612.60

Source: Odedra et al (1977).

Estimates of the heritability of economic traits are high; 0.13–0.48 for birth weight, 0.06–0.68 for weaning weight and 0.50–0.57 for weight to 12 to 24 months. However, reproductive efficiency and viability of zebu cattle are low, especially under traditional management. As a result, economic returns and response to selection are likely to be small. Most attempts to increase the productivity of zebu cattle have therefore used crossbreeding because the economic traits are also associated with substantial heterosis; 10–25% for age at puberty, 10–20% for calving percentage, 5–20% for viability, 10–20% for pre-weaning growth, 10–20% for post-weaning

growth, and 25–50% for F_1 cow productivity. Koger et al (1973) give an extensive account of the effects of crossbreeding *Bos taurus* with *Bos indicus* cattle. Examples of individual studies are given in Table 24. Nevertheless, maximum heterosis is only expressed when cows are well managed and fed according to their genetic potential.

Table 24. *Effect of crossbreeding on reproductive performance*

Type of animal	Percentage pregnancy or calving	Source
British cattle	78.7	Warnick et al (1960)
Brahman cattle	62.9	Warnick et al (1960)
British × Brahman	70.0	Warnick et al (1960)
Angus	85.1	Bazer (1973)
Brahman	60.9	Bazer (1973)
Angus × Brahman	88.8	Bazer (1973)
N'Dama	45.5	Egbunike (1984)
German Brown	77.9	Egbunike (1984)
N'Dama × German Brown	83.3	Egbunike (1984)

McDowell (1985), in an extensive review of the merits of crossbreeding *Bos taurus* and *Bos indicus* cattle, found that crosses with European breeds calved earlier than local herd-mates, gave more milk per lactation, milked for more days and had slightly shorter calving intervals. F_1 crosses generally performed better than indigenous breeds and had fewer health problems. The author noted, however, that 3/4 crosses tended to calve nearly 1 year later and have calving intervals approximately 1 month longer than F_1 crosses. They also had higher early mortality rates and a tendency towards shorter herd life. Similar conclusions were reached by Franke (1980) in a review of work on Brahman cattle.

4.8 Summary

If meat and milk production are to be increased in the tropics, cow productivity, i.e. the number of calves produced per lifetime or per unit land area, must be increased and the time from birth to slaughter must be reduced. The number of animals available for finishing is also critical. Much of the information presented in this chapter suggests that the number of animals available for finishing would increase substantially if heifers were bred as early as physiologically feasible.

Fertility rates of *Bos indicus* cattle under traditional management are generally low but improve considerably, to 70–80% and more, under improved management. Calving intervals also shorten under improved management. Improving animal nutrition in traditional systems would increase animal productivity, and economic ways to achieve this need to be investigated.

The useful life of zebu cattle ranges from 4.5 to 8.5 years, during which they produce 3 to 5 calves. Very high levels of inbreeding depress fertility and fitness traits, while crossbreeding appears to increase both traits.

However, maximum benefit from crossbreeding is realised only when animals are well managed. Very high levels of taurine blood seem disadvantageous in tropical areas.

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5. INFERTILITY IN COWS

Cattle are deemed infertile when they are neither normally fertile nor completely sterile. Interest in bovine infertility increased with the introduction of artificial insemination in the 1950s and as the factors involved became known to farmers, herdsmen, physiologists and other workers (Roberts, 1956).

The causes of infertility are many and can be complex (Arthur, 1982). They relate to Graafian follicle development and maturation, oestrus onset, successful coitus, ovulation, fertilisation, implantation, and the development and delivery of the foetus and its membranes. Anything interfering with these routines, such as diseases, poor nutrition, inadequate herd management, hereditary and congenital factors, hormonal disturbances or environmental changes, makes the animal infertile, if only temporarily (Osmanu, 1979).

Ten to 30% of lactations may be affected by infertility and reproductive disorders (Erb and Martin, 1980), and 3–6% of the herd is culled annually in developed countries for these reasons. The extent of the problem is likely to be similar in the tropics, although extensive data are not available. In Zambia, for example, the National Council for Scientific Research (NCSR, 1970) noted that infertility is one of the major problems confronting the cattle industry, but that the extent and causes were still obscure. Although it was believed that up to 40% of local cattle were infertile, no systematic studies had been undertaken at that time. Details are given below of some of the common causes of infertility.

5.1 Congenital morphological causes

Congenital causes of infertility are often inherited. They include developmental abnormalities of the ovaries, oviducts, uterus, cervix, vagina and vulva. Some are lethal, a few have a morphological significance and others a functional significance. Common morphological conditions include ovarian (gonadal) hypoplasia and aplasia, anomalies of the tubular genitalia, hermaphroditism, freemartinism, arrested development of the Mullerian ducts (White heifer disease) and double cervix (Lagerlof, 1963). Many of these abnormalities have been documented in zebu cattle by Perkins et al (1954), Kodagali (1974), Chenna (1980) and Kumi-Diaka et al (1981). However, they are of little significance if an appropriate culling programme is practised.

Among 5238 non-pregnant slaughter cattle studied in Brazil, 17.27% had abnormalities of the ovaries and other reproductive tract segments, including agenesis, atrophy, hypoplasia and tumours (Vale et al, 1984). Segmental aplasia of the Fallopian tubes and uterus, abnormalities of the cervix and remnants of the Mullerian ducts were also observed by Basile and Megale (1974) among 6054 cows and heifers in southern America. Fifty had abnormalities of the hymen. Kumi-Diaka et al (1981) found anoestrus and genital abnormalities in 22.7% of 3000 cows in Nigeria, including ovarian

hypoplasia in 13 cows and freemartinism in two. A 9.7% incidence of hypoplasia was found among 889 cows examined over 6 years in Southern Kartanaka, India (Hussain and Muniraju, 1984).

Bovine gonadal hypoplasia is not easy to diagnose (Lagerlof, 1963) and in cases of bilateral ovarian hypoplasia heifers do not develop secondary sexual characteristics. They are anoestrus and infertile. Where the condition is unilateral, normal sexual organs and oestrous activity may be observed. Such animals are fertile, although less so than normal. The condition is potentiated by an autosomal recessive gene with incomplete penetrance, and therefore the incidence of gonadal hypoplasia can be reduced by using only animals (both male and female) with normally developed sexual organs as breeding stock.

5.2 Functional causes of infertility and repeat breeding

In a sample of 510 Gir cattle in India, functional abnormalities were responsible for 59.4% of the cases of reproductive disturbance, compared with 23.3% attributed to pathological causes, 8.8% to anatomical factors and 4.8% to old age (senility) (Kodagali, 1974). The causes of functional infertility included cystic and inactive ovaries with anoestrus, early embryonic mortality with repeat breeding, and prolonged gestation. Anoestrus often reflects a hormonal disturbance and accounted for 47.8% of the cases. Repeat breeding, where cows require three or more services to conceive, accounted for 11.5% of cases. Singh et al (1981) also found functional infertility to be more common than infertility due to infectious diseases (76 vs 24%).

5.2.1 Cystic ovaries and retained (persistent) corpora lutea

Cystic ovaries contain one or more persistent fluid-filled cavities larger than a ripe follicle (Arthur, 1964). This is sometimes referred to as cystic ovarian disease (Chauhan et al, 1984). Ovarian cysts can be classified as follicular and luteal. They may vary in size from that of a ripe follicle to that of an orange. Their effects also vary according to their number and degree of luteinisation. Many unluteinised follicles tend to lead to nymphomania with frequent, irregular heats, whereas a cow with a few extensively luteinised cysts may become anoestrous. Cows with long-term cysts may show virilism. In addition to the pathologic follicular and luteal cysts, there are the non-pathologic cystic corpora lutea. These are normal structures that follow a normal ovulation but have a fluid-filled central cavity 7–10 mm in diameter. On rectal palpation they feel like normal corpora lutea but more fluctuant and soft. They do not alter the oestrous cycle duration and when conception occurs, it can be maintained to term (Roberts, 1971). The term "cystic ovaries" is therefore usually applied to pathological follicular and luteal cysts.

Estimates of the incidence of cystic ovaries in zebu cattle range from 1 to 13% (Rao et al, 1965; Kumi-Diaka et al, 1981; Pandey et al, 1982; Hussain and Muniraju, 1984). Osmanu (1979) found that in the 26% of cows surveyed in Ghana that were infertile, the single most important cause was cystic ovaries. Kaikini et al (1983) found the right ovary to be affected more (5.1%) than the left (1.2%) and only in 0.5% of cases were both ovaries affected simultaneously. The above are interesting observations since cystic ovaries have seldom been reported among taurine beef cattle or zebu cattle.

Cystic ovaries are conventionally diagnosed by rectal palpation, but it may be difficult to differentiate between follicular and luteal cysts Although both tend to be smooth and convex, follicular cysts are more tense and thinner-walled.

Events in the hypothalamus, anterior pituitary, adrenals, ovaries and other target organs appear to be involved in the development of cystic follicles (Vandeplassche, 1982). There seems to be a break in the secretion of gonadotrophic-releasing hormone by the hypothalamus, which increases the ratio of follicle-stimulating hormone (FSH) to luteinising hormone (LH) in circulation. Insufficient LH results in failure to ovulate and no corpus luteum develops. Both follicular and luteal cysts are thus anovulatory, in contrast to the ovulatory cystic corpus luteum.

There appears to be a genetic predesposition to cystic ovaries. Estimates of the heritability of cystic ovaries range from 0.05 to 0.43 (Casida and Chapman, 1951; Erb et al, 1959; Johannson, 1960).

The incidence of cystic ovaries also appears to be related to milk yield in dairy cattle. Animals of all ages are susceptible, but incidence is greater in cows during their fifth or sixth lactation, i.e. when milk yield is often greatest. The condition is also commonly diagnosed 1–4 months after calving. It is thus suspected that lactation stress is a predisposing factor. Menge et al (1962) reported a genetic correlation of 0.22 between milk production and cystic ovaries, but Casida and Chapman (1951) found no correlation between the two factors. Hernendez-Ledezma et al (1984) observed that the incidence of cystic ovaries increased from 8.4% in primiparous cows to 25.9% in cows in their fifth lactation. The incidence overall was also higher in cows with metritis (14.6%) and those with retained placenta (13.6%) than in healthy cows (8.5%). Other factors influencing incidence were prolonged interval from calving to first detected oestrus, first mating and conception, and the interval from first detected heat to conception.

Vandeplassche (1982) indicated that a close association may develop between cystic cows (the bullers) and certain herdmates and that this increases the likelihood of the "chosen friends" becoming cystic. He also noted that treating cows with small dose of oestradiol benzoate may induce cystic ovaries.

Forage legumes are often advocated as a means of improving animal nutrition in the tropics. Some, however, contain substances, such as phytoestrogens, that may reduce fertility. Feeding cows for prolonged periods on clover, lucerne (alfalfa), or other plants rich in phytoestrogens may lead to cystic ovaries. Little (1976) assessed several pasture species, particularly tropical legumes, for oestrogenic activity and found that lucerne (*Medicago sativa*) had a slight oestrogenic potential. More evidence is needed on the oestrogenic effects of forage legumes, especially where they form an important component of natural pastures.

As noted above, cows with cystic ovaries can show either nymphomania or anoestrus. Nymphomaniac cows exhibit prolonged periods of frequent oestruses. They mount others and stand for mounting, even by a bull. In contrast, cows with virilism mount others but do not stand for mounting. Nymphomaniac cows have been called "bullers" because of these homosexual tendencies. They develop oedema of the vulva, copious mucous discharges may be seen and the sacro-sciatic ligament frequently sinks, causing the coccyx to tilt up.

Follicular cysts are follicle-like structures more than 2.5 cm in diameter that persist on the surface of the ovary for more than 10 days (Roberts,

1971). They grow in a disorderly manner, fail to regress or undergo atresia and instead accumulate fluid. Since there is no ovulation, such cows are infertile until normal cycles resume.

Follicular cysts during the early postpartum period may regress by themselves but several therapeutic approaches have also been tried. Products with high LH activity have long been used to treat follicular cysts, to good effect (e.g. Casida et al, 1944; Roberts, 1955; Elmore et al, 1975). Seventy to 80% recovery rates have been recorded, although subsequent first service conception rates tended to be low. Progestational compounds have also been used, but their efficacy is still in doubt. LH-rich products administered in conjunction with progesterone compounds have given better results than either product alone. More recently gonadotrophic-releasing hormone (GnRH) or its analogues have been used to induce LH release; this initiated oestrus in about 80% of the animals (Kesler and Garverick, 1982) due to the induced preovulatory-like LH surge which might otherwise have been insufficient for normal ovulation and corpus luteum formation to take place. The interval from GnRH treatment to oestrus may be shortened by 18 to 24 days by injecting prostaglandin $F_2\alpha$ ($PGF_2\alpha$) 9 days after GnRH.

Care should be exercised when administering prostaglandins to cattle. Local haemorrhages have been observed at prostaglandin injection sites due to prostaglandins other than $PGF_2\alpha$ in some products. Large abscesses may develop at these sites due to anaerobic *Clostridia* spp. bacteria, introduced by unsterilised needles. Therefore, clean needles should be used for $PGF_2\alpha$ injections, or an antibiotic (e.g., 1 ml streptomycin) should be added to the $PGF_2\alpha$ dose.

When ovaries are undergoing cystic degeneration, the walls of the growing cystic follicle may degenerate. Oocyte development is terminated and about a third of the cysts may luteinise. Luteal cysts are thus less frequent than follicular cysts. Careful diagnosis is needed to differentiate them from cystic corpora lutea, which are not pathological. Luteal cysts have a larger antrum surrounded by several layers of luteal cells, which continuously elaborate progesterone, rendering the cow anoestrous. Continuously high progesterone levels may therefore be indicative of luteal cysts.

Pressure can be applied to luteal cysts to rupture them and express their lining (Arthur, 1964), but recovery rates tend to be low. Ovulation can also be induced by administering luteinising hormone (human chorionic gonadotrophin: hCG) or 0.5–1.0 mg GnRH (Vandeplassche, 1982). Most cows show oestrus 18 to 23 days after GnRH therapy. The interval from GnRH administration to oestrus can be shortened to 12 days by administering prostaglandins 9 days after GnRH (Kesler et al, 1978). Bovine luteal cysts are difficult to differentiate from follicular cysts and this may be the reason that $PGF_2\alpha$ therapy is often ineffective.

GnRH has also been used prophylactically to reduce the incidence of ovarian cysts. Administering the hormone 8 to 23 days (Britt et al, 1977) and 12 to 14 days (Zaeid et al, 1980) after calving was found to reduce the number of cows that developed ovarian cysts or were culled for infertility.

Finally, reference has sometimes been made to retained or persistent corpora lutea, i.e. those that persist beyond the normal luteal phase. These continue to produce enough progesterone to prevent further follicular development, ovulation and oestrus. Severe endometritis may be associated with a persistent corpus luteum due to toxic damage to the endometrium, which prevents proper secretion of luteolytic prostaglandins. This can also

occur with pyometra, foetal mummification and maceration, i.e. conditions that simulate pregnancy (Boyd, 1977). Lamming (1977) reported persistent corpus luteum to be rare (under 2%) in cows with normal uteri.

Diagnosis of persistent corpus luteum is based on the presence of a large, persistent corpus luteum on the ovary, anoestrus and persistently high levels of progesterone. Frequent visits and rectal palpations of affected cows, with accurate records of the rectal findings at each visit, are required before a diagnosis of persistent corpus luteum can be confirmed. Once confirmed, the persistent corpus luteum can be enucleated or lysed by prostaglandins.

5.2.2 Other causes of anoestrus

Anoestrous cows have small, flaccid uteri and small, inactive ovaries with no palpable corpus luteum or follicle. In contrast, cycling cows are identified by the size and tone of the uterus and the presence of the corpus luteum or follicle or both on either of the ovaries. Nevertheless, cows may show anoestrus despite having normal ovarian structures.

Anoestrus is a major problem in the tropics and subtropics, where inadequate nutrition, high ambient temperature, high parasite burdens and disease exacerbate the problem. Low body weight and poor body condition, compounded with lactation stress, can further extend the postpartum anoestrous period. Vandeplassche (1982) indicated that the long anoestrous period in the nursing cow might be due to an elevated level of prolactin, which appears to depress the secretion and release of GnRH, or that the pituitary may be less responsive to GnRH during nursing. Since the anoestrous period tends to be longer and more common among first-calf heifers, the author also suggested that immaturity could be a contributing factor. Although the ovaries of such cows may not be completely inactive, reduction in oestrogen secretion over long periods may result in under-development of other genital organs. The vagina, uterus and ovaries of these animals feel inactive on rectal palpation. Blood or milk progesterone levels are also low.

Conditions that simulate pregnancy, such as pyometra (pyometron), severe metritis, foetal maceration or mummification, may cause anoestrus. Pyometra, which often occurs when foetal membranes are retained or following postpartum metritis, is a frequent cause of anoestrus. These conditions damage the endometrial lining of the uterus and reduce secretion of luteolytic prostaglandin. The cyclic activity of the ovary is thus interrupted in the luteal phase and the cow or heifer is anoestrous until the condition is corrected. Without regular veterinary care and palpation, these conditions may remain undiagnosed and the cow may be believed to be pregnant.

Although anoestrus can, to some degree, be overcome by treatment, it is more practical to ensure that animals are well managed and are fed to maintain good condition during critical periods, i.e. prior to mating and during lactation, in order to avoid anoestrus.

Anoestrus is normal in pregnant, prepubertal and recently-calved animals. Pregnancy is a common cause of anoestrus, but this is often overlooked where service records are poor. Since many treatments for anoestrus terminate pregnancy, the possibility that cows presented as anoestrous are pregnant should be eliminated before treatment begins.

5.2.3 Repeat breeders

Repeat breeders are those cows that require three or more services to conceive (Enkhia et al, 1983; Casagrande and Goes, 1977). Kaikini et al

(1983) estimated the incidence of repeat breeding to be 21.9% in 411 Holstein × Gir cross cows studied at Rahuri, India, between 1972 and 1980. Nuru and Dennis (1976) found that the incidence of repeat breeding ranged from 16.6 to 58.8% in Fulani herds surveyed in six states of northern Nigeria in 1972–73. Singh et al (1983) reported a range from 7.4 to 18.6% among Holstein, Danish Red and Sahiwal cows and their crosses.

Repeat breeding can be caused by a number of factors, including subfertile bulls, endocrine problems, malnutrition, reproductive tract infections and poor management. Vandeplassche (1982) cited previous work in which adhesions of the ovarian bursa, salpingitis, cystic ovaries and endometritis were found in repeat-breeding cows. Bhatt et al (1979) found antibodies to seminal antigen in the genital secretions of 12 repeat-breeding cows in Bikaner, India. Munoz de Cote et al (1980) made a similar observation in Mexico; 32 out of 50 infertile Holstein cows had antibodies, at a titre of 1.8 or more, to Holstein bull spermatozoa while none of 50 fertile heifers had a titre higher than 1.8. Thirty of the "infertile" Holstein cows conceived when inseminated with zebu semen, whereas only 7 of the "infertile" cows inseminated with Holstein semen conceived. Proper diagnosis of the cause of repeat breeding is very important and requires a careful assessment of production and breeding records.

Repeat breeding can be treated by enucleating the corpus luteum or causing its lysis by prostaglandins, uterine massage or manual stimulation of the clitoris after artificial insemination or infusion of the uterus with 50–200 ml of 1 to 5% Lugol's iodine, which has a stimulating effect on the uterus. Enucleation of the corpus luteum may cause adhesions between the ovary, bursa and fimbria or haemorrhage in the ovary. Pharmacological enucleation with prostaglandins avoids this problem. Intra-uterine infusion of antibiotics has been used but there is little evidence that this increases fertility during the following cycle. However, fertility tends to increase by the second or third heat after treatment. Human chorionic gonadotrophin can be administered at the time of AI to promote ovulation or progesterone can be injected 4 to 5 days after service. Details are given in the following sections on how pathological causes can be handled.

5.3 Infectious causes of infertility

Infectious agents that have a detectable effect on the animal may interfere, if only slightly, with its reproduction. These include several bacterial, protozoan, viral and mycoplasmal infections. Details of the most common and economically important ones are given below. Several are important zoonoses. Some details on endometritis, metritis, pyometra and retained afterbirth are also given.

5.3.1 Bacterial and protozoan infections

Pathological lesions were observed in the reproductive tracts of 55.14% of 700 cows examined at post-mortem on two ranches in Shaba, Zaire (Binemo-Madi and Mposhy, 1982). Most of these were on the ovary and salphinx. They may have been caused by abnormal rectal manipulations or bacterial infections of the uterus, vagina and vestibulae. About 45% of the cows were still capable of breeding, indicating that pathological conditions do not necessarily render cows permanently sterile. Their seriousness depends on the location of the infection.

5.3.1.1 Brucellosis

Importance and incidence

Brucellosis is found world-wide. It affects humans, domestic animals and wildlife. It is caused by *Brucella abortus, B. melitensis, B. suis, B. ovis* and *B. canis*.

De et al (1982), in a study of 989 cows in West Bengal, attributed abnormal termination of pregnancy, cervicitis, endometritis, repeat breeding and anoestrus to brucellosis, campylobacteriosis, leptospirosis and trichomoniasis. Rao et al (1977), Hussain and Muniraju (1984) and Kaikini et al (1983) noted that these, and other infections, can lead to inflammation with bursal and uterine adhesions, periglandular fibrosis, hydro- and pyo-salphinx, hydrometra, pyometra, endometritis, vaginitis, and metritis. Other effects include early embryonic loss and repeat breeding, abortion, dystocia, retained membranes, stillbirth, and prolapse in late gestation.

Brucellosis has been extensively studied, partly because it causes widespread economic losses due to abortion and extended calving intervals and because it affects humans.

Many countries in the temperate regions have substantially reduced the incidence of brucellosis. Some, such as Denmark, UK, The Netherlands and Romania, have eradicated the disease, mainly through rigorous test and slaughter policies. The diagnosis of brucellosis is now well standardised and, in general, highly efficient. However, the disease is still prevalent in many countries, especially in the tropics.

The reported incidence of brucellosis in Africa varies from zero to 100% (Chukwu, 1985; 1987). Some of the variation can be attributed to sampling technique, the herds sampled and the diagnostic tests used. Some cows also only react positively to serological tests when pregnant. Therefore, one must be cautious in interpreting incidences across countries or among herds.

A survey of cattle on the Accra plains in Ghana indicated an incidence of 20–30%, with high rates of abortion and stillbirth (Oppong, 1966). Esoruoso (1974) reported that up to 60% of breeding cows and heifers in western Nigeria were infected with *Brucella abortus*. In Ethiopia, Meyer (1980) found that 39% of the cattle belonging to the Institute of Agricultural Research (IAR) were serologically positive for brucellosis in 1978, compared with 18.1% in 1975. A comparatively low incidence of 0.25% was reported in Malawi by Klastrup and Halliwell (1977). Studies on brucellosis in Africa are reported by Dafalla (1962), Mustafa and Nur (1968) and Mustafa et al (1976) in Sudan; Waghela (1976) in Kenya; Kagumba and Nandhoka (1978) in Uganda, Kenya and Tanzania; Marinov and Boehnel (1976) in Tanzania, and Wernery et al (1979) in Somalia. These, and reports by Chukwu (1985; 1987), Vandeplassche (1982), Blood et al (1979), Arthur (1964), Roberts (1971) and Tekelye Bekele et al (1989a), are drawn on subsequently.

Transmission

Brucellosis is normally acquired by cattle by ingesting the bacteria. Infection may also occur through the mucosa of the eye, nose and teat, and through the endometrium if the cow is artificially inseminated with infected semen. The multi-layered mucosa of the vagina seems to protect against infection following natural service.

The disease is most serious in cows infected during pregnancy. The bacteria show a preference for the pregnant uterus, foetus and the lymph

glands of the udder. Both the membranes and foetus respond to *Brucella* infection by increasing their production of erythritol, a simple carbohydrate, which increases the growth rate of the bacteria. This usually results in abortion at about 6 to 8 months of gestation. The organism may also produce toxins and allergens, cause vascular thrombosis, increase uterine motility, and disturb production of sex steroids and prostaglandins, contributing to abortion (Vandeplassche, 1982). In some cases the dead foetus is not aborted, but is retained in a mummified or macerated form. If a calf is born alive it is likely to be weak and to contract calf scours easily. Many die soon after delivery.

Aborting infected cows or heifers are a major source of infection for other cattle and people handling them. Aborted material and vaginal discharges from infected females are heavily infected with *Brucella*, and these contaminate pastures, pens and buildings. Organisms are also present in the milk of infected cows. Brucellosis is a professional hazard for cattle keepers and veterinarians.

Foetal membranes are commonly retained because of uterine inertia, placentitis or both. Retained membranes must be handled with great care. Puerperal metritis may develop and cows may remain infertile for some time.

After abortion, uterine infection normally declines within a month. The animal may not abort on the next conception, but she will continue to discharge the *Brucella*. Some calves are born infected. Many lose the infection quickly but a few do not. The latter do not show any signs of the disease and represent "latent infection". The organism remains dormant until the animal becomes pregnant. Calves born to serologically positive dams are, therefore, at risk of developing the disease in the future and ought to be carefully screened when pregnant. Udder (Alton, 1981) and milk infection lasts several months or years and may be the source of uterine infection during subsequent pregnancies.

Diagnosis

Brucellosis should be suspected whenever a cow aborts unexpectedly, except in a *Brucella*-free herd. Confirmation requires bacteriological examination, culture of the organism or serodiagnosis.

A smear from the necrotic surface of placental cotyledons, stained with 20% fuchsin, 3% acetic acid and 10% methylene blue, can assist the first tentative diagnosis of brucellosis. The Brucellae stain red against a blue background. Chlamydiae may also stain red but are smaller and primarily intracellular (Vandeplassche, 1982).

The bacteria are rarely cultured, partly because diagnostic material, particularly foetuses, usually reaches the laboratory in a condition unsuitable for proper examination. Serological tests are, therefore, commonly employed. However, the various tests used differ in convenience and accuracy. A good serological test would establish early diagnosis, identify chronic infections, and distinguish between the antibodies of vaccination and infection (Fensterbank, 1986).

In the milk ring test (MRT), also called the Bang Ring Test, a drop of haematoxylin-stained antigen is added to 1 ml of milk. This is incubated at 37°C for half to 1 hour. This test is widely used, fairly efficient, economical and easy to perform. A positive result is shown by the development of a clump of stained organisms deposited in a ring on the surface of the preparation. The negative result is bluish milk covered by an uncoloured layer of cream. However, the sensitivity and specificity of this test are low,

and test results can even vary for the same animal at different periods. It is therefore used only for quick screening or surveillance of milk samples. Milk should be tested monthly. To reduce the chances for misdiagnosis, such as can arise after Strain 19 vaccination or due to the presence of certain milk proteins in late lactation, test milk can be diluted 5 to 10 times with normal (*Brucella*-free) milk.

In the spot agglutination test, developed in the United States (Alton, 1981), a drop each of serum and antigen are mixed on a card or on a plastic, ceramic or glass plate. This is also known as the Rose Bengal Test (RBT) or rapid plate agglutination test. RBT is performed on serum using stained antigen at pH 3.6. It is economical, simple to perform and gives results in 4 minutes. Like the MRT, it is used as a quick screening test. A positive result is indicated by clear agglutination. To aid judgement, a known positive sample is run at the same time for comparison.

More sensitive and specific tests include the complement fixation test (CFT), which detects IgG_1 and IgM antibodies (Fensterbank, 1986). This is the most accurate and sensitive test for brucellosis and distinguishes between antibodies of infection and vaccination. However, it must be performed by a trained technician.

The enzyme-linked immunosorbent assay (ELISA) has been used to diagnose brucellosis (Stemshorn et al, 1960), but has not been extensively adopted as a routine test. Diaz et al (1979) described a simple immuno-diffusion test that they thought could differentiate between infected and vaccinated animals. Kaneene et al (1979) reported that the level of immunity among vaccinated cattle could be assessed by exposing peripheral lymphocytes to *Brucella* antigen in vitro. They also indicated that this procedure could be used to diagnose the disease.

Control

Brucellosis can be controlled through strict hygiene in the handling of potentially infected material and by vaccinating all animals. To eradicate the disease, all infected animals must be slaughtered.

Cows, especially those that react positively to serological tests for brucellosis, should be isolated from the herd before calving and their calves monitored for latent infection. Pregnant animals should be observed for imminent abortion and all aborted material must be disposed of properly, e.g. by burning or deep burial. Farm labourers should be aware of the dangers of brucellosis and avoid spreading the disease.

Cattle should be bought only from *Brucella*-free herds. If this is not possible, animals should be tested serologically on the farm of origin prior to purchase and again one month later after arrival on the new farm. They should be kept in quarantine until after the second test. If an animal reacts positively to the MRT or RBT tests, the result should be checked using the CFT test. If the latter is also positive, the animal should be slaughtered.

Where the incidence of brucellosis is high, calves should be vaccinated with the attenuated Strain 19 vaccine at 3 to 6 months old. Persistent antibody titres that may be hard to distinguish from infection, and infection of the udder, have been observed in heifers vaccinated at 8 months or older. Vaccinal titres tend to recede more rapidly when heifers are vaccinated at 6 months or younger (Carroll, 1972) and there is no difference in immunity levels of calves vaccinated at 3, 4, 6 or 8 months old (Mathei and Deyoe, 1970). Sexually mature animals can be vaccinated with the killed adjuvant vaccine 45/20. The vaccine is given twice, 6 weeks apart, followed by an annual booster. The resistance developed is similar to, but not better than,

that from calfhood vaccination using Strain 19. Therefore, it is not advisable for heifers that received Strain 19 as calves.

Bulls should not be vaccinated. Strain 19 organisms have been isolated from the genitalia of vaccinated bulls (Lambert et al, 1964). These could infect their seminal vesicles, epididymides and testes. Bulls often stay in the herd for a short time, during which they do not transmit the organisms naturally. However, bulls at artificial insemination centres must be rigorously tested for the disease. Non-specific post-vaccination reactions to serum agglutination tests have also been observed among AI bulls. Bell (1984) believed that the cause could be an anomaly of the immune system, particularly of IgM.

Prevention of the disease in humans is contingent upon the control of the disease in animals. Once the incidence of the disease is substantially reduced by vaccination, a test and slaughter programme can be attempted to eliminate infected animals. Once a herd has been certified as being free of the disease, continuing vaccination may not be necessary but the herd must be kept closed.

5.3.1 2 Trichomoniasis

Incidence and transmission

About 40 years ago, trichomoniasis was an important cause of infertility in cattle in many countries. The disease causes endometritis, pyometra, abortion and sterility. It is a venereal disease spread at service or by artificial insemination with improperly treated or handled semen. It is sometimes called Bovine Venereal Trichomoniasis. Its incidence has been greatly reduced where artificial insemination is widely used, as in the UK, The Netherlands, France and Cyprus. It nonetheless remains a problem in other countries, especially in dairy cattle, poorly managed herds and herds which use communal bulls.

The incidence of trichomoniasis in Africa and the tropics is not widely reported, partly because diagnosis is complex and time-consuming. Consequently, it is not clear if the disease is widespread. De et al (1982) did not find infected animals among 13 well-managed herds in West Bengal, India. Only one cow from a rural herd was diagnosed as being infected. Klastrup and Halliwell (1977) also failed to demonstrate the disease among 294 slaughter bulls and 54 others maintained at breeding centres in Malawi. However, in Egypt, Gawade et al (1981) found an incidence of 4.6% among Holstein bulls, and in Nigeria Akinboade (1980) found an incidence of 14.9% among slaughter animals.

Trichomoniasis is caused by *Trichomonas fetus*, a protozoan about 15 μ long with an undulating membrane. In bulls, the trichomonads normally colonise the crypts of the external mucous membrane of the penis and prepuce. Since these crypts are deeper in older bulls, the prevalence of the disease tends to increase with bull age. Infection does not induce any local antibodies or specific agglutinins in the blood of bulls. Bulls carry the disease for a long time without showing symptoms.

Cows and heifers that have never been exposed to the disease become infected following either natural service by a carrier bull or artificial inseminations with contaminated semen. Following natural service, the protozoa first multiply in the vagina and cervix for about 3 weeks. In about a quarter of the cows, the organisms do not migrate to the uterus. With intra-uterine artificial insemination, the uterus is directly infected.

Importance

Trichomoniasis causes infertility, repeat breeding, delayed return to oestrus after mating, early embryonic death and, sometimes, abortion. It may directly cause the death of the embryo or may do so via uterine endometritis and marked leucocytic diapedesis into the endometrium (Vandeplassche, 1982). The affected cow returns to oestrus or may abort anytime from 2 to 7 months after conception. The foetus can degenerate. The corpus luteum may be maintained because the endometrium does not secrete luteolytic prostaglandins. Mucus accumulates, resulting in mucometra. Pus may eventually be observed, indicating pyometra. However, the parasite tends to attack the superficial layers of the endometrium and cow fertility usually returns to normal.

Affected cows develop agglutinating antibodies in their vaginal mucus. This, together with hormonal changes during subsequent oestrous cycles, tends to protect the cow during an infection but may not protect her from re-infection. Withdrawing infected cows from breeding for at least 3 months and subsequent use of clean bulls or artificial insemination can help control the disease.

Diagnosis

A low 60- to 90-day non-return rate, together with a large number of repeat-breeding cows and cows that exhibit purulent vaginal discharges, endometritis, abortion and pyometra, might indicate trichomoniasis. The symptoms of trichomoniasis and campylobacteriosis are similar. Both lead to irregular inter-oestrous intervals. They are best differentiated by isolating the causative agents.

Initially, preputial washings, semen or smegma from bulls should be examined microscopically for the presence of trichomonads. For preputial washings, about 50–100 ml of physiological saline is introduced into the prepuce under gravity or from a syringe and tube. The prepuce is closed and agitated vigorously for 2 to 3 minutes to free any organisms present in the crypts of the penis and prepuce mucous membrane. The fluid is collected, centrifuged and the supernatant discarded. The residual is shaken and a drop examined at 100x magnification, preferably with a cover-slip, at 37°C on a warm slide stage. To collect preputial secretions (smegma), a dry plastic uterine infusion pipette attached to a 12-ml syringe is introduced into the fornix of the unprepared sheath, the syringe is opened to 10 ml and the pipette is moved back and forth. About 0.2 to 1.0 ml of smegma can be obtained, which is rinsed into 3 ml of physiological saline.

Cervical and vaginal mucus can also be examined but this is only really useful during the first few weeks of infection. Thereafter, the motility of the trichomonads diminishes and only the undulating membrane can be discerned at 250x magnification. In the case of an abortion, microscopic examination of foetal fluids, placental secretions and foetal abomasal contents can be useful.

Isolation of even one trichomonad, from either the cow or the bull, confirms diagnosis. Only few trichomonads may be present and, if the disease is suspected, a second sample should be taken if no trichomonad is found in the first. Samples should be examined within 6 hours of sampling as the parasite tends to die within 6 hours of leaving the animal's body. At temperatures lower than 37°C the undulation of the parasite tends to slow or stop. Thus techniques suitable for field studies in the tropics need to be developed.

As an alternative to direct examination, preputial washings or purulent discharges can be cultured, preferably within 6 hours of sampling. Immediate inoculation onto specific culture media is advisable. Where this is not possible, especially under field conditions, transport media may be used.

Buffered saline solution with foetal bovine serum, and lactated Ringer's solution are simple and effective transport media. Vandeplassche (1982) suggested Difco-Lash medium (No. D-1016T), and Oxoid medium as culture media. Klastrup and Halliwell (1977) referred to two trichomoniasis culture media, one with and one without antibiotic, while De et al (1982) used Douglas' broth and glucose broth serum medium. Both direct examination and culture methods can take time to yield results. Sero-diagnostic procedures are generally unsatisfactory.

Treatment and control

Treatment of infected cows with vaginal antiseptics has not been very successful. In animals with pyometra, it is better to enucleate the corpus luteum or to lyse it with prostaglandins. Treatment may be repeated 10 or 11 days later.

Trichomoniasis is a "self-limiting" disease in the non-pregnant cow with an involuted uterus. After being sexually rested for 3 or 5 cycles, many cows develop some immunity and their fertility improves. Only clean bulls or semen should be used for breeding and cows with abnormal genital tracts should be culled.

"Carrier" bulls and sexually active oxen can re-infect treated, recovered and susceptible females and should therefore be culled. Carrier bulls can be treated, but treatment is lengthy and should not be considered unless the bull is very valuable.

The antibacterial agents used by artificial insemination centres to preserve semen do not control trichomonads. AI centres must therefore test their bulls regularly to ensure that they are not infected. Young bulls chosen as breeders should not be allowed in contact with untested teaser cows. Both teaser animals and bulls should be selected from disease-free herds whenever possible and held in quarantine prior to puberty and collection.

5.3.1.3 Campylobacteriosis

Incidence

Abortion in cattle and sheep was first associated with vibrionic organisms in 1918 by McFadyean and Stockman (cited by Laing, 1963). The organisms were first named *Vibrio fetus* by Smith (1918), and later *Campylobacter* species.

The species most commonly encountered in the bovine genital tract are *Campylobacter fetus* subsp. *venerealis* serotype A, *C. fetus* subsp. *fetus* serotype A and *C. fetus* subsp. *fetus* serotype B. Of these, infertility in cattle is most often associated with *C. f. venerealis* A (90%) and *C. f. fetus* B (10%) and only rarely *C. f. fetus* A and B (Vandeplassche, 1982).

The incidence of campylobacteriosis in the tropics varies. De et al (1982) found an incidence of 6.1% among 194 cows sampled on 13 well-managed farms in West Bengal, India. None of 295 cows from individual rural farms was affected. In Malawi, the incidence reported by Klastrup and Halliwell (1977) was 11.5% in 294 zebu and 11.1% of 54 exotic bulls tested serologically. When the vaginal mucus agglutination test was performed on the cows, it showed that 53.8% of the herds and 13.4% of the samples were infected. Using the same test in Zimbabwe, 33% of the cows sampled were found to be positive (Terblanche, 1979).

Transmission and pathogenesis

Campylobacteriosis is a venereal disease and although transmission via fomites and between bulls has been suggested, this is unlikely. Garcia et al (1983) stated that transmission is purely venereal or via artificial insemination, and that attempts to infect cattle by vulval contamination failed. Clark (1971) indicated that direct transmission of infection between cows probably does not occur naturally.

Events subsequent to infection are similar to those described for trichomoniasis except that the migration of the organisms from the vagina and cervix appears faster. In cows, infection is initially acute but eventually becomes chronic. Acute infection is associated with infertility and the chronic phase with abortion, although abortion may also occur in the acute stage (Garcia et al, 1983). Catarrhal vaginitis in the acute phase results in an increased production of clear, cloudy or muco-purulent discharge for 3 to 4 months. Catarrhal cervicitis may result in a reddening of the cervix. Once in the uterus, the infection flourishes, causing a low grade inflammation, and results in infertility lasting about 6 months (ABS, 1972). Abortion may occur at any time but usually occurs 5 to 6 months after endometritis and placentitis have occurred. The incidence of abortion can be over 5%. Foetal membranes are extensively affected. The intercotyledonary areas are covered by dark brown purulent material. The animal may recover spontaneously after 2 or 3 months despite the continued presence of the bacteria in the vagina. The bacteria may migrate into the oviducts and cause more permanent infertility due to salpingitis.

Ordinarily a large number of cows in a herd get infected from the same bull or improperly prepared semen. The bull is always a symptomless carrier; its genitals and semen appear normal. The inflammation in the female is low grade and diagnosis based on clinical signs may be difficult in the acute stage. Breeding records often give the first indication, with many cows returning to oestrus after repeated service: the repeat breeder syndrome (Table 25). Oestrous cycles are longer than normal, usually more than a month (Clark, 1971), indicating early embryonic death. After variable periods of infertility many cows recover and regain normal fertility. Thus, as with trichomoniasis, infected females should be sexually rested.

Infected cows develop local antibodies (IgG, IgM, IgA) in their genital tract mucus (Vandeplassche, 1982, citing work by others). The IgA antibodies may persist in the vaginal/cervical region for over 10 months. The antibodies that develop in the uterus are dominated by the IgG type (Vandeplassche, 1982), which results in rapid phagocytosis of *C. fetus* and recovery of the uterus in about 2 months. However, animals that recover may be less fertile than normal. The fertility of the herd will remain low as long as susceptible heifers and cows are present and infected bulls are used.

Diagnosis

Breeding records showing low non-return rates, many repeat breeders and a high incidence of abortion at mid-term suggest campylobacteriosis. Isolation of *C. fetus* from the bull or cows will confirm the diagnosis.

Campylobacteae can be isolated from the genital secretions (sheath washings or semen) of bulls. Hoerlein (1970) gives a detailed account of laboratory diagnosis of campylobacteriosis. Garcia et al (1983) indicate that the Bartlett technique for collecting preputial material using an AI pipette remains widely used. They cite Dufty and McEntee (1969), who showed

Table 25. *Comparison of the number of services per pregnancy in non-infected and* Campylobacter-*infected heifers*

Service on which conception occurred	Infected heifers (101)	Non-infected heifers (108)
1	5	54
2	8	32
3	10	11
4	12	3
5	17	3
6	12	2
7	6	2
8	6	0
9	1	0
10	2	0
11	1	0
12	2	0
Total	82	107

Source: Laing (1960).

that the aspiration method is more effective than preputial washing for recovering *C. fetus*, and Tedesco et al (1977), who observed that scraping the preputial and penile mucosa was superior to aspiration and washing methods. Special buffered saline should be used for washings (Vandeplassche, 1982). Various media have been recommended for initial isolation; Laing (1963) and Dufty and McEntee (1969) should be consulted for detail and to decide on which medium is most suitable for work in different locations.

Samples should be inoculated onto isolation media within 6 hours of sample collection. Where this is not possible, transport media should be used. *Campylobacteae* are difficult to culture and the immunofluorescent antibody (IFA) or fluorescent antibody (FAT) test is more convenient. At present the technique is specific for *C. fetus* but cannot differentiate between subspecies. Samples can be kept refrigerated for several days and still yield reliable results with this test. Using culture and FAT together gives results approaching 100% reliability. Where good selective media can be prepared the two methods make the virgin heifer test, whereby the suspect bull is test-mated to clean heifers, unnecessary.

A direct Gram-stain smear of an aborted foetus, placenta or foetal stomach may reveal the short "S" shaped organisms sometimes called "flying seagulls". Culture and FAT tests may then follow. Vaginal mucus can also be used for diagnosing campylobacteriosis. A vaginal mucus agglutination (VMA) test will indicate infection in a herd but does not reliably indicate infection in individual animals (Hughes, 1953) since the specific agglutinins (IgA) are only found in 50% of infected animals (Garcia et al, 1983). Mucus can be collected by aspiration using a glass or plastic AI pipette (Schurig et al, 1973). For serological purposes mucus may be recovered by a sponge tampon attached to a plunger (Hughes, 1953; Laing, 1963).

If samples are to be used in an effort to culture the organism they must be free of contamination and oxygen tension must be minimised to ensure the survival of *C. fetus*. This can be achieved with AI tubes that can be sealed

immediately or by storing samples in sealed tubes and shipping them at -70°C in dry ice. Alternatively, transport media can be used. The transport enrichment medium (TEM), after Clark and Dufty (1978), is useful in isolating *C. fetus venerealis*. It comprises solidified bovine serum with antibiotics. Organisms can be isolated from TEM kept at 22 to 23°C for 2 days using inocula as small as 100 organisms. The major advantage of TEM is that field samples can be shipped unrefrigerated to the laboratory. Other transport media, based on thioglycollate, cooked meat or veal infusion broth with charcoal powder, have been reported (Foley et al, 1979; de Lisle et al, 1982).

Treatment and control

Treatment should aim to cure the infected bull. Fat-free cream containing 1% neomycin or polymixin can be applied to the penis and prepuce under sedation. Streptomycin (Seger et al, 1966) or erythromycin have also been used, but both have been associated with false cure in bulls and cows. Cows can also be treated by infusing streptomycin or erythromycin into the uterus but this does not clear organisms in the vagina and cervix and the cow can be re-infected.

Infection with *C. fetus* does not induce immunity in bulls. Therefore, bulls can be re-infected after treatment. A curative treatment based on two doses of 50 mg *C. f. venerealis* (dry weight), 4 weeks apart, has been reported to overcome this problem (Vandeplassche, 1982). This can be coupled with infusion of antibiotic into the prepuce, intramuscular injection of streptomycin or intravenous injection of erythromycin to produce a cure that has little effect on semen production. A booster vaccine is necessary every year for cows (Carroll, 1972) to eliminate the disease from the herd. Table 26 shows the increase in fertility resulting from vaccination.

Table 26. *Effect of inoculation with commercially prepared attenuated* Campylobacter fetus *in infected herds*

	Vaccinated		Non-vaccinated	
Experimental herd	No	% pregnant	No	% pregnant
H96 South-east Colorado				
1 year heifers	70	83	53	39
2 year cows	32	66	29	38
H98 North-east Nebraska				
1 year heifers	26	81	23	43
H106 Central Colorado				
1 and 2 year olds	7	100	6	50
H107 North-east Colorado				
1 year heifers	147	48	150	8

Source: Hoerlein et al (1965).

Although control of the disease centres around preventing the introduction and spread of infection, this may be difficult in herds that use a communal bull. If more than one bull runs with the herd, it may be difficult to determine which bulls are infected. Artificial insemination with semen from uninfected bulls is thus one of the best ways to control the disease

(Roberts, 1971). Where this is not feasible, sexual rest of affected females combined with vaccination may be the best approach.

5.3.1.4 Leptospirosis

Importance and transmission

Bovine leptospirosis is a systemic disease characterised by fever and, sometimes, mastitis and abortion. Leptospirosis should be suspected when abortion occurs in cows showing other symptoms such as icterus and haemoglobinuria (Carroll, 1973). It is one of the most widespread zoonoses.

Leptospirosis has not been extensively researched in Africa. Moch et al (1975), working in Ethiopia, found incidences of 91.2% in horses, 70.7% in cows, 57.1% in pigs, 47.3% in goats, 43.4% in sheep, 15.4% in camels and 8.3% in dogs. Ball (1966) reported incidences of 34% in cattle and 9.3% in goats sampled in Kenya and Uganda.

The disease is caused by *Leptospira* bacteria. These are spirochaetes. Some 120 *Leptospira* serotypes have been identified by the World Health Organization (Moch et al, 1975). The serotypes associated with bovine abortion are *Leptospira pomona*, *L. canicola*, *L. australis*, *L. icterohaemorrhagica* and *L. grippotyphosa*. They are all sensitive to antiseptics and desiccation and their virulence and pathogenicity are highly variable. Lawson (1963) indicated that *L. pomona* is the serotype most commonly implicated in bovine abortion.

Animals infected with *Leptospira* excrete the bacteria in their urine. Direct or indirect contact with the urine of infected animals is the major route of infection in both animals and man. The usual route of infection is via the digestive tract, but the disease may be contracted via the respiratory and reproductive tracts, eyes or skin. In cows, infection is often followed by pyrexia and reduced milk production.

In the pregnant cow the organisms show an attraction for the uterus and attack the foetus or endometrial capillaries. This may result in abortion during the last trimester or the birth of a weak or dead calf. Aborted foetuses show no characteristic lesions other than subcutaneous oedema and fluid-filled cavities. Foetal membranes may be retained, sometimes causing metritis and infertility. The organisms also settle in the kidneys and in 2 or 3 weeks leptospiruria starts. If the bacteria invade the udder they may cause mastitis or agalactia. The udder is flaccid and milk becomes thick, yellow and clotted.

Antibody titres in the blood of infected cows are elevated after an initial temperature rise. The titres vary from 1:400 to 1:1000 depending on the serotype. Antibodies can disappear after 2 months. As a result, cows may continue to excrete the organisms in their urine.

Diagnosis

Leptospirosis should be suspected following abortion associated with acute illness and the presence of blood in the milk for some days. However, leptospirosis can cause abortion without giving any other obvious symptoms (Stoenner, 1968).

Leptospirosis is usually diagnosed from blood serology, despite major difficulties with interpreting the titres. As noted earlier, titres rise rapidly after infection. They tend to fall rapidly soon after abortion but may remain appreciable for years. Titres can drop from 1:1600 among aborting cows to 1:400, a titre that may also indicate a recent infection, in three weeks (Deas,

1981). Antibodies may even disappear. A positive titre in the blood or foetal fluid of an aborted foetus is, however, confirmatory.

The bacteria can be cultured but they are usually difficult to isolate from the foetus or membranes, because autolysis of the foetus between infection and abortion quickly results in the death of the bacteria. The bacteria are most readily isolated from the aqueous humour of the eye but can also be isolated from urine. The sample should be inoculated in a transport medium of 1% serum albumin and 5% fluorocil. This can keep Leptospirae alive for 4 days while inhibiting the growth of other bacteria. The presence of the disease is confirmed if the bacteria are seen under dark-ground microscopy or from the post-mortem histopathology of kidney tissue of culled animals. For more detail on the diagnosis and control of leptospirosis, consult Ellis and Little (1986).

Treatment and control

Leptospirosis can be self-limiting. Therefore, all newly-purchased animals should be kept in quarantine and tested for the disease. Hygiene measures outlined earlier for brucellosis should be applied in case of an abortion. Rodents on the farm should be controlled and contamination of drinking places should be avoided by isolating infected animals (Carroll, 1972).

Treatment with streptomycin readily eliminates kidney infection, protecting the herd and people handling the animals. Each aborting cow should therefore be treated with streptomycin at 25 mg/kg bodyweight. Cows usually abort once and may not have to be culled. However, cows that recover can be re-infected.

Carroll (1973) reported an effective vaccine against *L. pomona*. However, this vaccine does not protect against other serotypes. He recommended annual vaccination of animals in areas where the disease is prevalent.

5.3.1.5 Salmonellosis

Salmonellosis is an important cause of abortion in cattle. It is also a zoonosis. *Salmonella dublin* and *S. typhimurium* are the most common causes of salmonellosis in dairy cattle.

Infected animals excrete the organisms in their faeces, contaminating pastures, water supplies and housing. From these, the bacteria infect healthy animals. Typical symptoms of salmonellosis include septicaemia, pyrexia and dysentery. Pneumonia may also occur. The bacteria are attracted to the uterus and together with severe enteritis, caused by endotoxins, and painful arthritis, cause abortion (Vandeplassche, 1982). The primary cause of abortion is the release of prostaglandin ($PGF_{2}\alpha$) induced by salmonella endotoxin. Following abortion, the uterus may become severely inflamed, resulting in the death of the cow. Cows that recover may continue to excrete the bacteria for years.

Aborted foetuses show no striking features but membranes, retained in about 72% of the cases, are oedematous and yellow, with pus-like exudates. A tentative diagnosis based on these signs can be confirmed by isolating the bacteria from the stomach (abomasum) contents, liver or joints of the foetus, from the placenta or from the dam's faeces.

Salmonellae can be passed to humans. Aborted material should therefore be handled with extreme care. It is difficult to cure carrier animals, and the best control measure is therefore to cull all animals that react positively to tests for salmonella. All animals thought to be infected should

be isolated subject to confirmation by isolating the bacteria. This approach is likely to result in better control of the disease than vaccination.

5.3.1.6 Non-specific bacterial infections

Many species of bacteria inhabit the vagina, uterus, and cervix of cows. Some are symbionts that become pathogenic when the animal is stressed; others are immediately pathogenic.

Namboothripad and Raja (1976), Eduvie et al (1984) and El-Azab et al (1988) isolated *Staphylococcus aureus, Escherichia coli, Pseudomonas pyocyanea, Corynebacterium pyogenes, Proteus mirabilis, Streptococcus* spp., *Pasteurella multocida, Proteus vulgaris, Klebsiella* spp. and several anaerobic micro-organisms from the uteri of cows with a history of repeat breeding, retained placenta and metritis, as well as from the uteri of normal suckling cows. *Mycobacterium tuberculosis* was isolated by Mohanty et al (1980) from a Haryana heifer that was a chronic repeat breeder.

Listeria monocytogenes may also cause abortion in cattle. When the organism infects a pregnant cow, it invades the foetal nervous system and forms necrotic foci on the liver, lungs and spleen (Watson, 1979), killing the foetus. Vandeplassche (1982) indicated that, although the organisms are easily eliminated from the uterus, they may persist in the mammary system. Antibodies to *Listeria* are short-lived, and immunity is thus only temporary and cows can be re-infected. Treatment is often futile, even with antibiotics.

5.3.2 Viral infections

Several viral diseases, including infectious bovine rhinotracheitis (IBR), bovine virus diarrhoea/mucosal disease (BVD/MD), para-influenza-3, G-up, infectious (contagious) bovine epididymitis and vaginitis complex (Epivag), transmissible fibropapilloma and epizootic bovine abortion have been associated with cattle infertility (Florent, 1963; Gledhill, 1968; McKercher, 1969). The major infections are described below.

5.3.2.1 Infectious bovine rhinotracheitis

Infectious bovine rhinotracheitis (IBR) is caused by a herpes virus. Its incidence in Africa is not widely reported but a recent field study by ILCA on two populations of indigenous Ethiopian zebu cattle indicated a prevalence of over 50% (Tekelye Bekele et al, 1989b). IBR can affect the respiratory, reproductive, nervous and digestive systems of cattle. The disease can be transmitted sexually or by droplet inhalation; in its venereal form it has been associated with infertility.

Cows and heifers served by an infected bull develop a pustular vulvo-vaginitis 2 to 3 days later. This may clear up after 2 weeks. Some develop superficial ulcers on the mucosa of the vestibulum and may discharge yellowish pus. Infection rarely extends directly to the cervix or uterus, and therefore pregnancy is rarely terminated. However, if cows are artificially inseminated with semen from an infected bull, the virus is deposited directly into the uterus and induces endometritis. Infection of the uterus disrupts the cow's oestrous cycles and reduces its fertility. The virus may also invade the uterus systemically in cows suffering the respiratory form of the disease.

After invading the uterus the virus may remain dormant for several months. Abortion occurs after 4 to 7 months. The foetus dies soon after being invaded by the virus. The dead foetus may be retained for several days

and appear mummified when finally expelled. Haemorrhagic fluid and oedema may be seen in the foetal pleural and peritoneal cavities, with focal necrosis, particularly of the liver.

The above signs indicate IBR. The presence of the disease can be confirmed by isolating the virus from the foetal brain, liver, spleen or lung tissues, placentomes or swabs from the nose, eyes, penis or prepuce. The virus grows best in bovine foetal kidney cell cultures. It can be identified by serum neutralisation or immunofluorescence inhibition tests.

The results of the neutralisation test may be difficult to interpret. Specific antibodies appear 8 to 10 days after infection and persist for 10 to 20 days (Polydorou, 1984). In general a titre of 1:32 in a sample taken 10 days after the cow aborted indicates a recent infection. Standard conditions should be followed and maintained while performing the neutralisation test because serum dilution, time and temperature of heating the serum, and the time at which the neutralising effect is read affect the sensitivity and reproducibility of the test.

Antibody titres decline after about a month and the antibodies may even disappear. However, even animals that show no serological reaction may remain latently infected. They respond to some stress factor by forming antibodies and shading the virus (Polydorou, 1984). Therefore, a single negative serological test should not be taken as an indication that the animal is not infected.

Control measures against IBR vary. In Switzerland and Denmark all cattle are tested for IBR and those reacting positively to the test are slaughtered. France monitors the disease in bulls because it can be spread in semen. In the Federal Republic of Germany, AI bulls must be vaccinated. None of these systems is used in the tropics.

Carroll (1973) noted a modified live vaccine against IBR. This provided good protection against abortion when given to cows that were not pregnant, but caused abortion in some pregnant cows. Todd et al (1971) reported that pregnant cows could be safely vaccinated intra-nasally.

5.3.2.2 Bovine virus diarrhoea

Bovine virus diarrhoea/mucosal disease (BVD/MD) is widespread. It is caused by a Toga-virus. Infection may be acute, mild or chronic. When the virus infects a pregnant cow it may also infect the foetus and kill it. Calves born alive may be stunted, with cerebellar hypoplasia, brain cavitation and mucosal ulceration. These signs aid diagnosis. Confirmation is by the demonstration of antibodies in foetal blood prior to ingestion of colostrum. A double sample with dam's blood is very helpful. A herd test will indicate if BVD/MD was prevalent at the time of abortion.

5.3.2.3 Infectious (contagious) bovine epididymitis and vaginitis complex

Infectious bovine epididymitis and vaginitis complex (Epivag) appears to be confined to East and southern Africa. It was first described in Kenya and subsequently in South Africa (Arthur, 1964). Epivag is a venereal disease. In cows the main symptom of Epivag is muco-purulent discharges from the vagina. Epivag can cause permanent lesions on the Fallopian tubes. In the bull, it causes the epididymis to swell, sometimes to the size of a golf ball. The disease can be controlled by slaughtering infected bulls and by using artificial insemination.

5.3.3 Mycoplasmas

Mycoplasmas are infective agents distinct from both bacteria and viruses. Several species of *Mycoplasma* cause disease in cattle. They have been associated with infertility, but their exact aetiological role is difficult to ascertain because they are present in the tracts of healthy animals.

In a study of cattle in South Africa, *Mycoplasma bovigenitalium* was found in 43% of males, 47% of females, 25% of foetuses and 11% of placentas (Trichard and Jacobsz, 1985). *Mycoplasma ergini, M. alkalescens, M. laidlawii, M. bovis, M. bovirhinis, M. verecundum* and *M. conjuctivae* were also isolated.

Mycoplasmas can be transmitted by discharges from the respiratory and reproductive tracts, and by milk, of infected animals. Infected cattle develop antibodies, but these do not give complete protection.

Symptoms associated with mycoplasmoses can also be observed with other conditions. Diagnosis can only be confirmed by isolating the organisms from nasal or reproductive-tract mucus and discharges, milk, arthral fluids, foetal tissues or the placenta. Consult Trichard and Jacobsz (1985) for procedural details of culture and serology.

The best way to control mycoplasmosis is to cull infected animals.

5.3.4 Endometritis, metritis and pyometra, and the use of prostaglandins in postpartum uterine pathology

Some of the systemic and non-specific infections discussed above can cause endometritis, metritis and pyometra. These pathological conditions are discussed below.

There is little information on the impact of metritis, endometritis or pyometra on the fertility of zebu cattle. Among *Bos taurus* cattle, Tennant and Peddicord (1968) found that endometritis, as indicated by pus in the vagina, significantly reduces fertility. Cows with endometritis required significantly ($P<0.001$) more services per conception (2.0 vs 1.6), had lower conception to first service rate (49 vs 62%, $P<0.001$) and longer calving interval (394 vs 383 days, $P<0.001$), and more animals were culled for infertility (13.6 vs 6.2%).

Infections of the reproductive tract are usually contracted at parturition. Non-specific infections of the uterus are more common where the placenta is retained, in cows that need assistance with calving and in cows with milk fever. Metritis is often also associated with uterine atony or inertia. Acute metritis causes fever and depression within a week of infection, and is commonly followed by chronic metritis, with persistent purulent vaginal discharge. Specific venereal infections, such as trichomoniasis, campylobacteriosis and brucellosis, may also lead to metritis.

Pyometra is the accumulation of pus in the uterus. It is a common cause of anoestrus and cows with pyometra should be treated promptly. Postpartum metritis, endometritis and pyometra may be common where cows and heifers are confined at delivery time in a building or area in which others have recently calved.

The uterus can resist or eliminate bacteria infection. However, this ability is related to ovarian activity (Paisley et al, 1986). The uterus is highly resistant to infection during the oestrogenic phase but very susceptible during the period of progesterone dominance, because (1) pH in the uterus is low, allowing greater bacterial growth, (2) the epithelium is less permeable to bacteria and therefore the leucocytic system is stimulated at a

later stage, (3) the appearance of leucocytes in the lumen is delayed, (4) the activity of leucocytes is decreased, and (5) uterine secretions have no detoxicating effect (Paisley et al, 1986). As a result, some cases of metritis resolve spontaneously when the animal's oestrous cycles resume, while others remain chronic.

Cows with chronic metritis are anoestrous and may have a retained (persistent) corpus luteum. Where a corpus luteum is present, initial treatment should aim at removing it. This is best achieved by an intramuscular injection of prostaglandin. If there is no corpus luteum, endometritis can be treated by infusing antibiotic or sulphonamides into the uterus. Application should be repeated every 2 days for a week. Alternatively, about 100 ml of 2% iodine can be infused into the uterus. The iodine solution is an irritant and stimulates new endometrial growth. Where the oviduct, deeper layers of the uterus or the cervix or vagina is infected, antibiotic should be given intra-muscularly.

Prostaglandin $F_2\alpha$ ($PGF_2\alpha$) reduces inhibition by progesterone of the uterine defence mechanism. Oestrogen secreted during the subsequent development of a follicle promotes uterine defence. $PGF_2\alpha$ may also stimulate myometrial contractions, helping to empty the uterus of lochia and pus. It may encourage phagocytosis. Jackson (1977) found that a single injection of $PGF_2\alpha$ cured pyometra in 90% of cases. The remaining 10% of cows were cured by a second injection. Prostaglandin treatment may thus be sufficient to clear pyometra and additional antibiotic therapy may be of little advantage (Fazeli et al, 1980).

Several other postpartum conditions can reduce fertility. Cervicitis and vaginitis often follow a delayed or complicated delivery. Metritis may cause abscesses in the uterus; if it spreads to the Fallopian tubes it may lead to salpingitis. Scars in the uterus and adhesions between parts of the reproductive tract can result in infertility or sterility. Routine examination of cows 1 or 2 months after delivery can diagnose such conditions early.

Irrespective of the condition, treatment should also aim at restoring the animal's normal hormonal status. Thus a persistent corpus luteum must be enucleated or lysed. Inactive ovaries should be stimulated using small doses of oestradiol benzoate (2–5 mg i.m.) or diethyl stilboesterol (20 mg i.m. or orally). Cows should be given a period of sexual rest of 2–3 cycles after treatment.

5.3.5 Retained afterbirth

Two to 30% of cows retain their foetal membranes for 12 to 24 hours after a normal delivery. The afterbirth, or foetal membranes, is retained if the cotyledonary villi fail to detach from the caruncular crypts. Membranes retained for more than 2 or 3 days decompose in the uterus, leading to metritis.

The incidence of retained afterbirth is often high in *Brucella*-infected herds, following a difficult delivery and in cows suffering certain nutritional and mineral (especially selenium) deficiencies. Grunert (1984) categorised the basic causes of afterbirth retention as: immature placentomes, oedema of the chorionic villi, necrosis between chorionic villi and the walls of the crypts, advanced involution of the villi, placentome hyperhaemia, placentitis and cotyledonitis, and uterine inertia.

Cows with retained afterbirth have poor appetite and reduced milk and meat yields. Their fertility is reduced, especially if metritis develops.

Treatment of the cow with retained afterbirth should be aimed at expelling the afterbirth and preventing infection of the uterus. In treating a

cow with retained afterbirth, it should be remembered that removing the afterbirth by hand may be harmful to the cow; it may cause haemorrhage, haematomas and vascular thrombi in the uteri, reducing subsequent fertility. The operator may also fail to remove all the afterbirth. There is also the risk of contracting brucellosis from handling retained afterbirths. Banerjee (1963) found, for example, that conception to first service among European *Bos taurus* cattle in which the retained afterbirth was manually removed was only 39%, compared with 50 % among cows in which no treatment or removal of the afterbirth was undertaken. Manual removal with an intra-uterine infusion of oxytetracycline also resulted in 39% conception to first service. In contrast, intra-uterine treatment with oxytetracycline alone without removal of the afterbirth resulted in the highest conception rate (70%). More recent work by Bolinder et al (1988), showed that manual removal delayed establishment of the first functional corpus luteum by 20 days in Holstein cows induced into parturition.

Proper animal husbandry can reduce the incidence of afterbirth retention. Animals should be sexually rested for at least 2 months after calving, fed a balanced ration, adequately exercised where they are continuously raised indoors and immunised against prevalent infectious diseases that cause abortion. Animals should not be unduly stressed and proper sanitation and management must be exercised at delivery; selenium should be added to feed where it is deficient (Youngquist and Bierschwal, 1985).

5.4 Summary

Among the common forms of functional infertility in cows are faulty oestrus manifestation including silent heat, inactive ovaries with anoestrus, cystic ovaries, abnormal oestrous cycle periodicity, and repeat breeding due to delay or failure of ovulation and fertilisation or early embryonic death. These forms of infertility tend to affect individual animals, but they are becoming more important as attention is paid to the environmental and health constraints.

Several systemic, genital and non-specific infections of the reproductive tract reduce the fertility of zebu cattle. Some are also important zoonoses. Their exact frequency in many areas is not precisely known and warrants further study.

The best way to control many of these diseases is to prevent contact between herds. If this is not practicable, herd owners should buy only virgin heifers as replacement stock. All newly introduced stock should be quarantined for 3 to 4 weeks before joining the herd.

Farmers should not buy bulls that have been used for breeding in other herds unless they are proved to be completely free of important diseases. Semen for artificial insemination should be obtained from reputable centres.

All replacement heifers should be vaccinated with Brucella Strain 19 vaccine when 3 to 6 months old. Older animals should be given Strain 45/20. Once the incidence of brucellosis has been reduced, the herd should be regularly tested and infected animals culled.

The modified live virus vaccine for infectious bovine rhinotracheitis confers good immunity, and all heifers should be vaccinated.

Cattle can be vaccinated against both campylobacteriosis and leptospirosis annually. The vaccines are, however, expensive and may not be readily available, and even a vaccinated bull can act as a passive vector after serving an infected cow.

Infections of the uterus can be largely avoided by having cows served and calved under hygienic conditions. Cows should be allowed plenty of room during calving, and the site should be clean. Bedding should be changed after each calving. When conducting obstetrical manipulations, use only disinfected instruments and disinfect both the operator and animal before and after any manipulations. If a birth is difficult, or otherwise abnormal, intra-uterine application of a broad-spectrum antibiotic will help prevent infection.

All infertile animals should be examined to determine the exact cause of their infertility. If a cow aborts, the aborted material should, if possible, be sent to a diagnostic laboratory to ascertain the cause.

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6. THE ROLE OF NUTRITION IN CATTLE REPRODUCTION

Many studies show the influence of nutrition on cattle fertility. Differences in nutrition probably account for most variation in reproductive performance between herds and among animals within herds (Wiltbank et al, 1964; McDowell, 1972; Holness et al, 1978). Level of feeding (Wiltbank et al, 1962) and bodyweight (Ward, 1968; McClure, 1970; Lamond, 1970) affect cow fertility.

The effects of underfeeding are greatest on pre-pubertal animals and lactating cows. Weight loss postpartum, due to underfeeding or high lactation demands, extends the postpartum anoestrous period (Entwistle, 1983). Underfeeding also reduces milk yield, which reduces the growth of the calf. This reduces calf weaning weight and delays puberty, which reduces the potential lifetime productivity of the female calf.

The effects of poor nutrition differ depending on whether the main deficiency is in energy, protein, vitamins, minerals or trace elements. Under traditional management, usually more than one component is deficient (Roberts, 1971).

The effects of nutrition on cattle reproduction are covered extensively here because most cattle in the tropics are poorly fed and improving their feeding can immediately increase their reproductive performance. For more detail, consult Cunha et al (1967), Lamond (1970), McClure (1970), Preston and Willis (1974) and Topps (1976, 1977).

The nutritional status of animals is difficult to measure, and this complicates interpretation of nutrition×reproduction interactions (Haresign, 1984). An animal's nutritional status is usually assessed on changes in its liveweight and body condition. However, these are long-term changes while many of the events of reproduction, e.g. ovulation, fertilisation and placentation, take only a short time.

6.1 Effect of nutrition on heifer pubertal development

Poor nutrition delays puberty, reduces conception rate and increases pregnancy losses in heifers (Short and Bellows, 1971; Milagres et al, 1979; Fleck et al, 1980; Lemenager et al, 1980). Wiltbank et al (1966) referred to a critical age-to-weight ratio which must be reached before heifers attain puberty.

Drought delayed the onset of puberty in heifers of 10 breed groups in Australia and stopped ovarian activity in half of those that had already reached puberty (Post and Reich, 1980). Bartha (1971) found that feeding concentrates to Azaouak zebu cows advanced puberty and first conception by 4 to 18 months. Penzhorn (1975) found that puberty was delayed by 7 months in Africander heifers on a restricted diet. All heifers attained puberty at about the same bodyweight (279-295 kg) but at different ages. Conception rates after a 3-month breeding period were 80, 93, 87 and 40%

for heifers on high, medium, low and restricted levels of nutrition, respectively. These data also indicate that overfeeding can reduce reproductive performance. Reid et al (1964) also found that heifers reared on a very high level of nutrition had more breeding problems subsequently than those fed moderately.

Supplementation need not be continuous. In Ethiopia, Azage Tegegne and his co-workers (ILCA, unpublished data) supplemented Boran heifers with 1.5 kg of concentrate (1/3 oilseed cake, 2/3 wheat bran) for 90 days during the dry season preceding puberty. Supplemented heifers reached puberty earlier (596.4 vs 633.5 days), were heavier at puberty (230.7 vs 202.4 kg) and had larger ovaries than unsupplemented heifers. The proportion of supplemented heifers bred in the subsequent breeding season (61.9%) was nearly twice that of unsupplemented heifers (33.3%). A similar trend was observed among Boran × Friesian heifers. These results agree with those of Olivares et al (1981) in Brahman heifers (Table 27).

Table 27. *Effect of prepartum and postpartum supplementation on the reproductive performance of Brahman heifers*

	I	II	III	IV
Prepartum cow weight loss (g/day)	770	737	1362	1366
Postpartum weight loss to 120 days (g/day)	41	81	163	162
% cows cycling	67	58	25	8
% cows conceiving	50	25	8	8
Calf weight at birth (kg)	27	29	28	29
Calf weight at 120 days (kg)	104	102	119	108

I = Fed 2 kg concentrates for 22-55 days prepartum and 90 days postpartum
II = Fed concentrates prepartum only
III = Fed concentrates postpartum only
IV = Received no concentrates (control)
Source: Olivares et al (1981).

Cohen et al (1980) found a direct relationship between bodyweight and incidence of oestrus in 603 heifers aged 17.2 to 19.2 months and weighing between 130 and 376 kg. The relationship between the percentage of heifers showing oestrus (Y, expressed as probit units) for a given weight (X) was:

$$Y = -40.69 + 19.34 \log_{10}X$$

The authors estimated that 5% of the heifers would show oestrus when weighing 187 kg or less, 50% would show oestrus when weighing 231 kg or less, and 95% would show oestrus when or before they weighed 280 kg.

6.2 Effect of nutrition on the postpartum cow

The reproductive performance of the postpartum cow is related to nutritional status (Dunn et al, 1969; van Niekerk, 1982). Cows fed a high energy diet after calving conceive sooner than those with a lower energy intake (Wiltbank et al, 1962, 1964; Dunn et al, 1969; Hill et al, 1970). Although protein is generally regarded as less important than energy for reproduction, low protein intake can also cause infertility. However, it may be difficult to differentiate the effects of low protein intake from concurrent low energy intake, because protein deficiency usually leads to decreased appetite.

Cattle in the tropics are usually dependent on natural pastures and crop byproducts for feed. The crude protein content of the feed is often below 7.5%, which reduces rumen efficiency and reduces the true digestibility of the feed. As a result, lactating cows are unable to meet their nutritional requirements and lose weight and condition during lactation. This prolongs the lactation anoestrous period, and cows tend to calve in alternate years (Ward, 1968). The percentage change in the cow's bodyweight during the first 2 weeks after calving is inversely related to the number of days to first ovulation (Stevenson and Britt, 1980; Butler et al, 1981).

High levels of feeding before calving reduced the postpartum anoestrous period in taurine cows (Bellows and Short, 1978). In addition, more cows exhibited oestrus before the breeding season and subsequent pregnancy rates were increased. King (1968) estimated that a 1% change in body weight resulted in a 1% change in first service conception rate. Similar results have been found in zebu cattle.

Feeding a high plane of nutrition to five anoestrous cows of each of four breeds for 45 days resulted in 65% resuming cycling and 55% ovulating, whereas the 20 cows kept on a low plane diet neither cycled nor ovulated (Dindorkar et al, 1982).

In Zambia, feeding zebu cows a sub-maintenance diet resulted in 55% of the animals stopping cycling within a year, whereas those on a maintenance diet continued to cycle normally (Rakha and Igboeli, 1971). The cows on the sub-maintenance diet also had a higher incidence of silent heats than the maintenance-fed cows. Two out of three oestrous cycles may be silent in underfed animals (Hale, 1974).

The growth and development of the foetus, parturition, lactation and involution of the uterus, all use energy. The energy used by these processes must be supplied to the cow if she is to rebreed soon after calving. Generally, the farmer will not be able to meet the cow's whole energy needs, and some will be met from body reserves or fat. Thus a cow in good condition is better able to meet the energy requirements of parturition, lactation and involution of the uterus, and will therefore rebreed sooner, than a cow in poor condition. Cows should be fed well for 22-55 days before parturition and, if possible, for 90 days after parturition (Olivares et al, 1981) (Table 27).

Improved pastures can also be used to improve cow nutrition. In Colombia, cows grazing improved pasture and supplemented with legume fodder had a conception rate of up to 64.4%, compared with 6.3% for cows grazing only unimproved pasture (Kleinhesterkamp et al, 1981). In Florida, beef cows grazing mixed clover/grass pastures at 0.55 ha per cow had higher conception rates than cows grazing pure grass pastures at 0.83 ha per cow (Warnick, 1976) (84 vs 48% in lactating cows): they also had higher weaning rates (84 vs 64%), a shorter postpartum anoestrous period (72 vs 90 days) and required fewer services to conceive (1.34 vs 1.40). Most lactating cows grazing the grass pasture did not cycle during the 90-day breeding season.

Hale (1975) found that underfed dry zebu cows stopped cycling when their weight fell to 320 kg from 390 kg. However, when the cows regained weight, they did not start cycling again until they were significantly heavier than the weight at which they stopped cycling.

Mukasa-Mugerwa et al (1989) estimated that traditionally raised zebu cattle in the Ethiopian highlands needed 8 months after they stopped lactating to attain a bodyweight and condition that allowed them to reconceive successfully. The average calving interval was 26 months despite

a lactation length of only 8 months. Fertility of grazing cows is therefore closely related to the liveweight change during the calving-to-service interval. The animal is likely to become sexually active only after it has regained much of its pre-calving weight.

Patil and Deshpande (1981) found that Gir cows that gained weight in the first three months after parturition showed heat during that period, while those that lost weight remained anoestrous. Cows that lost weight had lower blood glucose and serum protein concentrations than cows that gained weight, and the authors suggested that measurements of these could be used to indicate cows that might not show oestrus soon after parturition.

McClure (1968) found that cows with a blood glucose concentration of less than 30 mg glucose per 100 ml blood tended to return to service. Cows must, therefore, be on an adequate or rising plane of nutrition and gaining mass during the mating season if conception is to be successful (van Niekerk, 1982).

In Zimbabwe, Richardson et al (1975) found that a cow's ability to reconceive was a function of its final change in bodyweight at mating time, but was not related to its rate of bodyweight change from calving to midway through the mating season (Table 28). Similar results were reported by Ward (1968), Trail et al (1971), Steenkamp et al (1975), Meaker (1975) and Buck et al (1976).

Table 28. *Change in bodyweight as percentage of initial weight of cows and their subsequent conception rates*

Bodyweight[1] change (%)	Number of cows	Calving rate (%)	Bodyweight[2] change (%)	Number of cows	Calving rate (%)
−24	11	55			
−20	13	46	−20	4	25
−16	28	82	−16	6	67
−12	32	82	−12	11	64
−8	32	91	−8	29	69
−4	23	87	−4	36	78
0 to +8	31	84	0 to +20	87	90

[1] Bodyweight change between peak weight in early pregnancy and parturition.
[2] Bodyweight change between peak weight in early pregnancy and the following mating season.

Source: Richardson et al (1975).

In Botswana, Buck et al (1976) found average conception rates of 50% for cows weighing less than 300 kg at the beginning of the breeding season, 85% for cows weighing 430 kg, 67% for cows that lost weight over the breeding period and 76% for cows that gained 20 kg weight over this period.

6.3 The relationship between body condition and cow reproduction

Ward (1968) suggested that every cow has an optimum bodyweight for conception, the so-called "target" or "critical" bodyweight. Animals weighing less than this are less able to reproduce. Wiltbank et al (1964) added that breeding cows must be improving in "condition" during the mating period. This is emphasised in the work of Wiltbank (1977) (Table 29) and Haresign (1984).

Table 29. *Effect of cow body condition at calving on the cumulative percentage return to oestrus*

	Cumulative percentage return to oestrus					
	Days after calving					
Body condition	40	50	60	70	80	90
Thin	19	34	46	55	62	66
Moderate	21	45	61	79	88	92
Good	31	42	91	96	98	100

Source: Wiltbank (1977).

Condition scoring was started in Australia for assessing sheep fatness: it was introduced into the United Kingdom for the same purpose, and has since been extended to cattle. Condition scoring is a subjective visual assessment of animals, but with practice a high level of repeatability, both between measurements and between scorers, can be obtained (Nicholson and Butterworth, 1986). A condition score is based on the amount of fat and muscle tissue covering the skeletal frame and is indicative of the animal's nutritional status (van Niekerk, 1982).

The relationship between condition score and body fatness has been established from data on cows slaughtered at different body condition scores (Wright and Russell, 1984). Although the condition score gives a good indication of fatness, breeds differ in the way they deposit fat reserves. This is especially true of cows with more than 15% body fat. Dairy cattle generally deposit more fat internally than do beef cattle. Condition scoring tends to assess subcutaneous fat reserves, and therefore at a given condition score value dairy cows tend to have more fat reserves than beef cows.

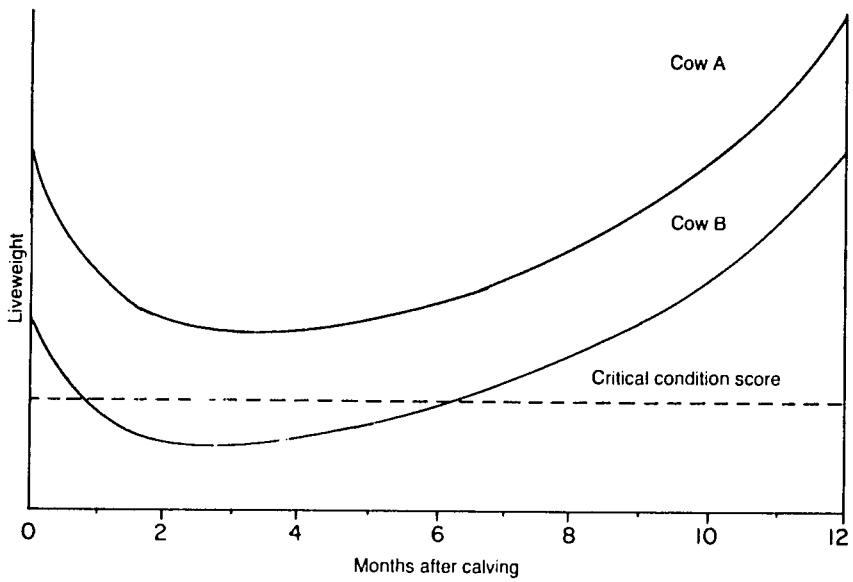
Changes in bodyweight or condition score of cows indicate likely levels of subsequent reproductive performance. The fertility of cows in poor condition is low. Cows below the "critical condition score" are least likely to reproduce (Figure 13).

Steenkamp et al (1975) compared the conception rates of cows of similar weight that differed in condition score and found that condition at mating was more important than weight. This agrees with the findings of van Niekerk (1982), who observed a calving rate of 78% for cows in optimum condition compared with just 8% for animals in the poorest condition (Table 30). The feed costs of maintaining the animals in this better condition are more than covered by increased reproductive performance.

Thus animals should be fed well to promote good reproductive performance. It is more efficient to feed animals to maintain good body condition than to allow them to lose weight in the hope that it can be regained before the mating season. Wright (1985) estimated that the loss of one unit in condition score would supply 3200 MJ of metabolisable energy: restoring the animal's condition score would require about 6500 MJ of dietary metabolisable energy. This agrees with van Niekerk (1982) who concluded that the feed cost of maintaining a cow at a condition score of 3.0 was half that required to raise a cow's condition from 1.5 to 3.0.

The benefits of feeding animals well in terms of better reproductive performance are often easily appreciated by peasant farmers. However, smallholders usually have only small supplies of supplementary feed and will need advice on which animals to feed it to, how much to feed and when.

Figure 13. *Pattern of liveweight change during the breeding cycle of the cow and its possible relationship to nutritionally induced infertility in the postpartum period*



Remarks: Negative energy balance itself is not likely to have much effect on the length of the postpartum period as long as the cow is in good condition at calving (Cow A) and its condition remains above the critical condition score, which is defined as that score below which cows still in negative energy balance (Cow B) are likely to suffer from extended anoestrous periods and silent heats.

Source: Haresign (1984).

Table 30. *Effect of condition score at mating on calving rate of cows*

Condition score at mating	n	Number of calves born per 100 cows mated
1.5	12	8
2.0	72	43
2.5	124	64
3.0	211	78
3.5	31	77

Source: van Niekerk (1982).

6.4 Hormonal changes associated with undernutrition

Few studies have been made on the relationship between bodyweight, condition and hormone synthesis or secretion in zebu cattle, and their results are inconsistent. However, in general the results suggest that poor feeding postpartum reduces luteal function and responsiveness of the ovaries to luteinising hormone (Gombe and Hansel, 1973; Martinez et al, 1984; Rutter and Randel, 1984; Whisnant et al, 1985).

6.5 Summary

Inadequate nutrition delays puberty and sexual maturity in heifers and resumption of ovarian activity and oestrus in postpartum cows. If a cow is

underfed when pregnant it will be in poor condition at calving, and will be slow to resume cycling and reconceive. Ideally, the cow's body condition should improve gradually through pregnancy, but excessive fatness should be avoided.

Cows will probably lose weight after calving, but weight loss should be minimised through good feeding to allow them to start cycling again as soon as possible.

More studies are needed to determine the physiological basis of the nutrition/reproduction interaction in zebu cattle.

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7. LACTATIONAL ANOESTRUS AND THE EFFECT OF WEANING

The postpartum anoestrous period is longer in suckled or intensively milked animals (Morrow et al, 1969). Continuous suckling delays the return to oestrus in taurine (Laster et al, 1973) and zebu cows (Fonseca et al, 1981; Bastidas et al, 1984; Wells et al, 1986) and results in depressed pregnancy rates (CIAT, 1974). Suckling tends to suppress growth of follicles (Carter et al, 1980) and blocks ovulation (Spicer and Echternkamp, 1986). However, neither the presence of the calf nor frequent milking appears to block the secretion of LH (Williams et al, 1987). Partial or restricted suckling and early or temporary weaning (also called strategic weaning) can reduce the postpartum anoestrous period and improve pregnancy rates (Montoni and Riggs, 1978; Reeves and Gaskin, 1981).

7.1 Early weaning

Early weaning can be particularly useful during periods of feed shortage or when the quality of feed available is low. It allows dams a chance to recover body condition and reconceive, and tends to reduce mortality among cows.

Early weaning (2.7 vs 9 months) increased the pregnancy rate in range cattle in Colombia from 21 to 96% (CIAT, 1974). Maree et al (1974) found that early weaning (2 vs 7 months) reduced the postpartum anoestrous period from 81 to 71 days and increased the average daily weight gain of the cows to first postpartum oestrus from 197 to 352 g. Separating the calf from its dam at 3 days old reduced the postpartum anoestrous period to 47 days and increased average daily gain to 744 g.

Cows whose calves die at or soon after delivery tend to calve every year. Thorpe et al (1981) noted that cows that were not lactating at the beginning of the breeding period had a conception rate of 89%, compared with only 40% among those that had calved late the previous season and still had a calf at foot. Other studies have made similar findings (Wiltbank and Cook, 1958; Rose et al, 1964; Saiduddin et al, 1967; Smith and Vincent, 1972; Laster et al, 1973; CIAT, 1976; Holness et al, 1978; Espaillat et al, 1979; Blantzer, 1982; Moore et al, 1983; Bastidas et al, 1984).

7.2 Temporary weaning

Temporary weaning involves the separation of the calf from its dam for a short period during lactation. Taurine cows have been observed to come in heat when their calves are temporarily weaned 40 to 50 days postpartum. The first oestrous cycle after parturition is often short (Edquist et al, 1984), even if it is due to temporary or early weaning.

Cows ovulate at their first oestrus after weaning their calf, and the ova released can be fertilised (Ramirez-Godinez et al, 1982). However, the corpus luteum tends to be short-lived, and regresses before the conceptus can block the release of prostaglandin and the pregnancy is not maintained.

Hormone therapy has been used to try to extend the life-span of the corpus luteum (Entwistle, 1983). Treating cows with progesterone 48 to 72 hours before removing their calves reduces the occurrence of short oestrous cycles and increases the proportion of cows that conceive.

Reports on the effects of temporary weaning are mixed. Some studies report restoration of oestrus within a few days of removing the calf (Rose et al, 1964; Symington and Hale, 1967), whereas others show that oestrus does not occur in response to temporary weaning (Hearnshaw, 1978).

7.3 Partial or restricted suckling

Under partial suckling, the calf is separated from its dam for part of the day to prevent continuous suckling. Partial suckling encourages earlier return to oestrus after parturition and earlier conception, and increases conception rates relative to continuously suckled cows (Table 31) (Britto, 1974; Montoni and Riggs, 1978; Fonseca et al, 1981; Blantzer, 1982; Randel, 1982; Bastidas et al, 1984).

Table 31. *Effects of restricted suckling on postpartum reproductive performance of zebu cows*

	Once-a-day suckling	Continuous suckling
Cows in oestrus by 60 days postpartum (%) (P<0.005)	57	29
Cows in oestrus by 90 days postpartum (%)	74	63
Conception rate (%):		
at 60 days (P<0.005)	31	12
at 90 days	61	44
Anoestrous period (d) (P<0.05)	57.1±4.19	72.24±4.35
Service period (d) (P<0.05)	71.42±3.72	82.27±3.80

Source: Blantzer (1982).

7.4 Implications of strategic weaning and partial suckling

The success of strategic weaning and partial suckling regimes depends largely on how well and economically the weaned calves can be reared.

One issue that needs further study is the optimum age for early weaning, particularly for calves that share their dam's milk with humans. Preston et al (1957) showed that calves could be reared on good quality forage from 3 weeks old, and Roy et al (1955) showed that calves can be successfully weaned at 8 weeks old and reared on grass alone.

The control of milk letdown in zebu cattle needs further investigation so that calves can be weaned early but cows can continue to produce milk for human consumption. Some studies indicate that up to 25% of zebu cows will let down milk without their calf being present (Diop, 1981; Furnemont, 1981). Early weaning with zebu cattle will only be truly feasible if difficulties with milk letdown in the absense of the calf can be overcome.

7.5 Possible physiologic basis of lactation anoestrus and possible hormonal initiation of cyclicity

Although the beneficial effects of strategic weaning and partial suckling are well documented, the physiological mechanisms involved are not clear. Most of the available information is for taurine cattle.

Changes in gonadotrophic hormone levels appear to have some effect. Luteinising hormone (LH) levels are lower during the first week after parturition in suckled cows than in cows that are not suckled (Randel et al, 1976). Cows that are not suckled exhibit episodic surges of LH by 7 days after parturition, whereas suckled cows do not (Carruthers et al, 1977; Forrest, 1979). The frequency and amplitude of these LH peaks, together with reduced sensitivity of the pituitary to LH-releasing hormone may be the cause of inhibition of ovulation in suckled postpartum Holstein cows (Carruthers and Hafs, 1980; Carruthers et al, 1980). High suckling intensity reduces serum LH concentrations (Forrest, 1979). Suckling reduces the concentration of prolactin in the follicular fluid and inhibits release of LH from the pituitary following treatment with gonadotrophic-releasing hormone (GnRH) (Kaltenbach and Dunn, 1980).

The length of the postpartum anoestrous period in beef cattle is negatively correlated with basal LH concentrations and is positively correlated with the number of prolactin peaks (Chang et al, 1981). Suckling suppresses the release of gonadotrophin from the pituitary; removing the calf removes this suppression and hence allows follicles to develop in the ovaries (Carter et al, 1980).

Suckled cows remain anoestrous longer when poorly fed than when well fed (Fonseca et al, 1981). Hansel and Alila (1984) stated that the primary causes of postpartum anoestrus in cows in the tropics are poor management, disease and malnutrition, rather than a basic inability of the reproductive tract to function efficiently. Sound management practices tend to shorten the anoestrous period (Tevitt et al, 1977).

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8. REPRODUCTIVE HERD HEALTH PROGRAMMES

Reproductive herd health programmes are necessary to achieve and maintain the reproductive efficiency of cattle and hence boost the income from them. Such programmes consist of visits every 2 weeks or a month by a veterinarian to farms or cows. Where the number of cows owned by individual farmers or herders is small, groups of farmers can assemble their animals in one place to make fullest use of the veterinarian's visits.

During his or her visits, the veterinarian should examine:

- cows that calved in the last 15 to 45 days (postpartum examination) for normal recovery;
- cows bred within the last 35 to 60 days (pregnancy diagnosis);
- cows that have not shown oestrus at the expected time or those that have been served but failed to settle;
- cows and heifers known to have reproductive abnormalities, infections and other causes of infertility; and
- bulls used for natural service to determine their breeding soundness.

Each visit should have four "phases": identification and history, clinical examination, rectal examination and treatment.

8.1 Identification and history

Animal records should include the cow number or other means of identification, and its origin, breed, age, weight, body condition score, parity, date and ease of last calving, pueperium, lactation, nutrition management, housing, dates of heat and last service, and type of service (artificial insemination or natural), with details of the bull or semen used. Comments about sexual behaviour may be added if available. All records should be organised on a well planned, individual animal record card. An example is shown in Figure 14.

8.2 Clinical examination

After identifying the animal it should be clinically examined. In particular, the external genital system should be examined; observations should include the size, position and shape of the vulva, and the presence and type of any discharges and crusts. Ideally the vagina should be examined using a speculum and a light for discharges (their amount and origins), degree of closure (pneumo-vagina), mucosal lacerations and cervicitis. All equipment used should be properly cleaned between animals.

8.3 Rectal examination

A disposable glove, or one that can be washed after use, should be used. This protects both the cow and the veterinarian. Examination generally starts with the cervix. The uterine body, the bifurcation and both uterine horns should then be checked for symmetry, tone, pregnancy or abnormal

Figure 14. *Example of an individual cow card for gynaecological examinations*

Cow Name or Number	Birth date	Dam	Sire	

REPRODUCTIVE CYCLES

FIRST CYCLE			SECOND CYCLE			THIRD CYCLE		
Date	Findings	Code	Date	Findings	Code	Date	Findings	Code

KEY

Code		Findings		Findings	
NC	Normal calving	R	Right	H	Horn
AC	Abnormal calving	L	Left	N	Normal
RE	Rectal examination	O	Ovary	T	Tone
T	Treated	F	Follicle	G	Good
AI	Artificial insemination	OD	Ovulation depression	F	Flabby
BS	Bull service	CH	Corpus haemorrhagium	E	Oedema
NB	Not bred	CL	Corpus luteum	C	Cervix
P	Pregnant	I	Inactive/static	V	Vagina
E	Oestrus	U	Uterus	P	Pus

Remark: Each cycle starts with the first heat among heifers and calving for cows.

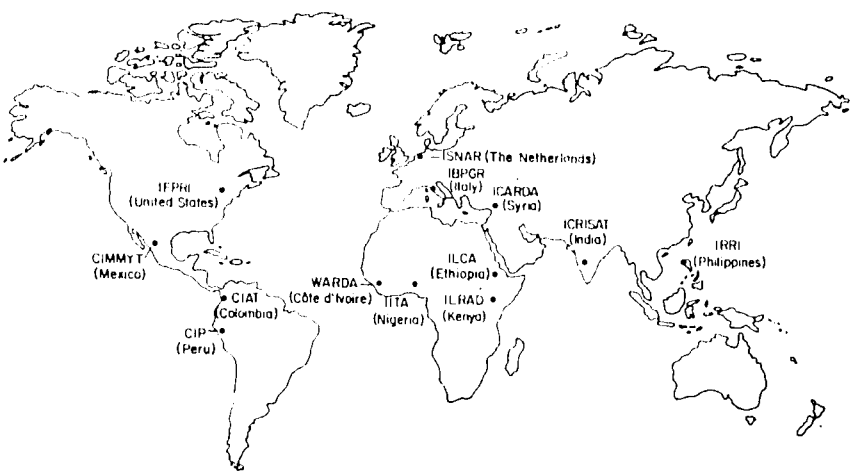
contents. The ovaries should be carefully palpated for the presence and size of normal follicles, corpora lutea or abnormal structures. If possible, the ovarian bursae should be examined for adhesions; the oviducts should be examined for abnormal contents, growths and septum formation. For accuracy, the examination should be repeated soon after and all findings entered on the animal's card.

8.4 Treatment

Pathological conditions found during the examination should be treated, if possible. Treatments for most reproductive disorders are discussed in other chapters of this book. However, many reproductive problems can be avoided by using good management practices, and farmers should be advised of these. Therapeutic interventions are no substitute for sound management and husbandry.

THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

The International Livestock Centre for Africa (ILCA) is one of the 13 international agricultural research centres funded by the Consultative Group on International Agricultural Research (CGIAR). The 13 centres, located mainly within the tropics, have been set up by the CGIAR over the past two decades to provide long-term support for agricultural development in the Third World. Their names, locations and research responsibilities are as follows :



Centro Internacional de Agricultura Tropical (CIAT), Colombia: cassava, field beans, rice and tropical pastures

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico: maize, wheat and triticale

Centro Internacional de la Papa (CIP), Peru: potato and sweet potato

International Food Policy Research Institute (IFPRI), USA: analysis of world food problems

International Board for Plant Genetic Resources (IBPGR), Italy

International Service for National Agricultural Research (ISNAR), The Netherlands

West Africa Rice Development Association (WARDA), Côte d'Ivoire: rice

International Institute of Tropical Agriculture (IITA), Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima bean, soybean)

International Laboratory for Research on Animal Diseases (ILRAD), Kenya: trypanosomiasis and theileriosis of cattle

International Livestock Centre for Africa (ILCA), Ethiopia: African livestock production

International Center for Agricultural Research in the Dry Areas (ICARDA), Syria: farming systems, cereals, food legumes (faba bean, lentil, chickpea), and forage crops

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India: chickpea, pigeon pea, pearl millet, sorghum, groundnut, and farming systems

International Rice Research Institute (IRRI), Philippines: rice

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