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Review

The postpartum buffalo: I. Endocrinological changes and uterine involution

A.B. El-Wishy *

Theriogenology Department, Faculty of Veterinary Medicine, Cairo University, P.O. Box 12211, Giza, Egypt

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Abstract

To maintain a calving interval of 13–14 months in buffaloes, successful breeding must take place within 85–115 days after calving. Disturbances during this period due to delay of uterine involution or resumption of estrous activity are likely to prolong the calving interval and reduce the lifetime reproductive and productive efficiency.

In this article literature on endocrinological changes in the peripartum period and on factors affecting uterine involution are reviewed. The available information indicated that although the availability of releasable FSH does not appear to be a limiting factor for resumption of postpartum cyclicity a substantial increase of releasable LH and replenishment of pituitary stores occurred around Day 20 in dairy and Day 30 in swamp buffaloes. There is evidence that follicular activity is resumed early (15–30 days) in the postpartum period. However, the factors which initiate release of appropriate LH pulses, follicular maturation and ovulation in the postpartum buffalo need further studies. The mean interval to complete uterine involution varied widely between 19 and 52 days. Assessment of cervical and uterine horn diameters by rectal palpation alone is not satisfactory to diagnose delayed uterine involution and possible subclinical uterine infection. Vaginal inspection can be included as a fundamental part of postpartum genital examination for diagnosis of such case. Uterine involution, however, does not seem to be a limiting factor for achievement of satisfactory fertility in the postpartum buffalo but the main determinant is resumption of estrous activity.

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Keywords: Buffalo; Postpartum period; Endocrinological changes; Ovarian changes; Uterine involution

* Tel.: +20 3442358.
E-mail address: bakerelwishy_2006@yahoo.com.

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1. Introduction

The postpartum period in the buffalo like the cow starts with parturition and ends with complete uterine involution and resumption of cyclic ovarian activity and normal estrous expression. Hormonal changes during the peri-parturient period besides regulating lactogenesis and parturition have their impact on postpartum reproductive activity. Knowledge of these changes is essential to understand the factors responsible for initiation of cyclic ovarian activity following parturition. Also information on the factors which influence the rate of return of the uterus to the nongravid size and function are important for determining the time of successful breeding.

In this article pertinent literature on hormonal changes during late gestation and postpartum period, initiation of follicular activity after calving and factors which influence uterine involution period are reviewed.

2. Endocrinological changes

2.1. Pituitary gonadotrophins

2.1.1. FSH

The basal plasma levels of FSH in Murrah buffaloes exhibited a significant reduction ($P < 0.05$) from Days 60 to 240 of gestation (Palta and Madan, 1996). During the postpartum period, based on single blood samples, the baseline levels were 7 ± 0.8, 11.8 ± 1.7 and 12.0 ± 1.8 ng/ml on Days 2, 20 and 35, respectively (Madan, 1985). Palta and Madan (1995) found that basal FSH levels on Day 20 were higher than those on Day 2 ($P < 0.01$) but did not differ from those on Day 35. On the contrary, no significant variations in plasma FSH levels between Days 3 and 90 or between milked (38.3 ± 1.5 ng/ml) and suckled (35.7 ± 1.5 ng/ml) Murrah buffaloes were reported by Arya and Madan (2001a). In the cow changes in basal plasma FSH levels are not thought to be critical for initiation of the first postpartum ovarian cycle (Dobson and Kamonpatana, 1986).

Pituitary release of FSH in response to exogenous GnRH declined progressively with the advancement of pregnancy (Palta and Madan, 1996), but remained similar with no significant variations between Days 2, 20 and 35 postpartum (Palta and Madan, 1995). Hence the latter authors concluded that availability of releasable FSH does not appear to be a limiting factor for resumption of estrous activity in the postpartum buffalo.

2.1.2. LH

All the studies on changes of LH levels during the postpartum period in buffaloes involved sampling at intervals of 24 h or longer. Very frequent sampling regimes are required to disclose the time of resumption of appropriate pulsatile pattern for ovulation and reestablishment of cyclicity. This pattern has, however, been proved during the periovulatory period of induced estrous cycles in buffaloes (Singh et al., 1998).

Basal plasma LH concentrations in the buffalo did not vary between 60 and 240 days of gestation (Palta and Madan, 1996). During the last stages of pregnancy, LH values ranged between 0.4 and 0.9 ng/ml in dairy buffaloes (Galhotra et al., 1981; Barkawi et al., 1986). In Swamp buffaloes mean values of 0.34 ± 0.36 and 0.43 ± 0.56 ng/ml were reported during 10 days before and after parturition (Kamonpatana, 1984).

In postpartum buffaloes with no history of estrus or ovulation low serum LH levels were noted during the first 4 months (0.6 ± 0.11 to 1.1 ± 1.3 ng/ml) with no significant differences (Galhotra

et al., 1981). Also no significant variations were observed in the basal LH levels between Days 3 through 90 postpartum or between milked (0.9 ± 0.2 to 1.3 ± 0.2 ng/ml) and suckled (0.9 ± 0.1 to 1.5 ± 0.2 ng/ml) anestrous Murrah buffaloes (Arya and Madan, 2001a). On the contrary a progressive increase of basal LH concentration occurred from Days 2 through 35 postpartum (Palta and Madan, 1995). Mean values of 0.5 ± 0.01, 1.3 ± 0.03 and 2.2 ± 0.1 ng/ml were given by Madan (1985) for Days 2, 20 and 35 postpartum, respectively. Batra and Pandey (1983) reported that basal plasma LH concentration during the second and third week was inversely related to the first postpartum ovulation interval. The levels were also significantly higher in buffaloes showing estrus than in anestrous animals. Daily blood sampling from anestrous buffaloes 6–8 months after calving revealed small increases (3–9 ng/ml) probably implying estrogen secretion due to follicular growth and regression (Razdan et al., 1981).

The responsiveness of the pituitary gland to exogenous GnRH declined during pregnancy (Palta and Madan, 1996) but was drastically increased (408%; $P < 0.01$) between Days 2 and 20 postpartum. Hence it was hypothesized that the capability of the pituitary gland to respond to exogenous GnRH is restored by Day 20 postpartum in dairy buffaloes (Palta and Madan, 1995). A corresponding period of 30 days was noted in suckled swamp buffaloes (Jainudeen et al., 1984).

3. Steroids

3.1. Estrogens

A progressive increase of estradiol-17β was observed as early as 241–243 days of gestation (Arora and Pandey, 1982) but marked increase of total estrogens (El-Belely et al., 1988) and estradiol-17β (Eissa et al., 1995; Savaiya et al., 1993) occurred only in the last 15–5 days. Peak values of estradiol-17β of 142.0 pg/ml (Barkawi et al., 1986) and 210 ± 27 pg/ml (Prakash and Madan, 1986) were achieved either 1 or 2 days before parturition or on the day of calving. Also total estrogens reached their maximum values of 251 ± 17 and 240 ± 10 pg/ml in buffalo cows and heifers, respectively, at the day of calving (El-Belely et al., 1988).

After parturition the mean plasma levels of estradiol-17β dropped steeply over the first 24–72 h (Arora and Pandey, 1982; Pahwa and Pandey, 1983; Prakash and Madan, 1984b). Basal values were reported between Days 2 and 7 after calving (Prakash and Madan, 1986; Eissa et al., 1995; Arya and Madan, 2001b) with minor fluctuations thereafter (11 ± 3 to 18 ± 3 pg/ml) until day 45 postpartum (Madan et al., 1984). The levels were higher in milked than in suckled buffaloes (Tiwari et al., 1995). Fluctuations of total estrogens between 38 ± 10 and 61 ± 5 pg/ml (level during estrus 63 ± 10 pg/ml) during the first 75 days postpartum in acyclic buffaloes (Soliman et al., 1981) probably reflects waves of follicular growth and atresia.

As regards estrone sulphate, peak values of 7 ± 4 ng/ml (Kamonpatana, 1984); 7 ± 0.4 ng/ml (Hung and Prakash, 1990a) and 6 ± 0.1 ng/ml (Eissa et al., 1995) in the last 30–15 days prepartum were reported. An abrupt drop on the day of calving or the day before was described with basal values of less than 0.1 ng/ml reached 1–2 days postpartum.

3.2. Progesterone

The literature on plasma progesterone concentrations in the last stages of gestation are rather conflicting. A clear increase of progesterone concentration was reported during the last 30–15 days (Perera et al., 1981; Kamonpatana, 1984; Momongan et al., 1990). Peak values of 3 ± 0.3 ng/ml

on Day −1 for buffalo heifers (El-Belely et al., 1988) and 5 ng/ml on Day −5 for mature buffaloes (Pathak and Janakiraman, 1990) were noted. On the contrary gradual decrease starting 30–17 days before calving (Arora and Pandey, 1982; Prakash and Madan, 1984a; El-Belely et al., 1988) with a sharp decline as early as 8 days (Eissa et al., 1995) or as late as 1–3 days before parturition (Batra et al., 1982; Barkawi et al., 1986; Prakash and Madan, 1986) were described. Nevertheless, irrespective of the above mentioned debate, in all cases a precipitous decline of progesterone level occurred on the day of calving. In some reports (Kamonpatana, 1984; Prakash and Madan, 1985, 1986; Momongan et al., 1990; Savaiya et al., 1993; Eissa et al., 1995; Tiwari et al., 1995) basal values of 0.1–0.6 ng/ml. were reached during calving suggesting complete luteolysis at parturition, with no significant changes during the postpartum period. In others decline of progesterone continued during the postpartum period to reach minimum levels on Day 6 (Bahga and Gangwar, 1988; Bahga, 1989) to Day 15 (El-Belely et al., 1988), indicating complete regression of the corpus luteum of pregnancy. However, a wider range between 3 and 29 days for complete regression of the corpus luteum of pregnancy was reported by Pahwa and Pandey (1983). Demise of the corpus luteum after calving expressed by progesterone concentration on Day 3 postpartum was not different in milked and suckled buffaloes (Arya and Madan, 2001b).

The relationship between the patterns of estrogens and progesterone in the last stages of gestation and during calving in relation to placental delivery or retention, uterine torsion and degree of cervical dilation as well as response to exogenous glucocorticoids for induction of parturition (Prakash and Madan, 1986; Nanda and Sharma, 1986; El-Belely et al., 1988; Balasubramanian and Rajasekaran, 1998) need further studies.

For a variable period after parturition progesterone levels remained basal but a transient elevation may occur before resumption of cyclic activity (Barkawi et al., 1986; Perera et al., 1987; Sharma and Kaker, 1990; El-Wishy et al., 1992; Ghoneim et al., 1999; Shah et al., 2004).

4. Corticosteroids

The plasma levels of corticosteroids are significantly increased during the last 12 days of gestation (Eissa et al., 1995) or somewhat earlier during the last 30–15 days (Kamonpatana, 1984). Peak values of 17 ± 3 and 10 ± 8 ng/ml were reported by the aforementioned authors, respectively, on the day of calving. On the contrary little change in mean plasma cortisol level was detected from Days 30 to 2 before delivery (1.3–1.5 ng/ml) with a sharp increase to 4 ± 0.4 ng/ml at calving (Prakash and Madan, 1986). During the period of fetal expulsion cortisol levels showed wide fluctuations between 0.6 ± 0.9 and 11 ± 7 ng/ml (Kamonpatana, 1984). The levels declined within 6 h after parturition (Prakash and Madan, 1984a) and remained below 3 ng/ml from Days 2–3 to Day 15 postpartum (Heshmat et al., 1985; Eissa et al., 1955). Nevertheless, fluctuations between 1.7 ± 0.4 and 2 ± 0.3 ng/ml were reported by Prakash and Madan (1984c) up to 50 days postpartum.

5. Prostaglandin FM

A gradual increase of peripheral plasma concentrations of prostaglandin metabolite occurred over the last 15–7 days prepartum (Perera et al., 1981; Batra et al., 1982; Eissa et al., 1995) to reach peak values of 4 ± 0.3 ng/ml (Prakash and Madan, 1985) on the day of calving. Higher concentrations of 14 ± 2 ng/ml were reported during delivery (Eissa et al., 1995) which then dropped to 5–8 ng/ml during the first 6 days postpartum. Lower values of 4 ± 0.5 ng/ml on Day 1 after delivery and 1.3 ± 0.2 ng/ml (Prakash and Madan, 1984a) and 0.4 ± 0.3 ng/ml (Madan et al.,

1984) on Day 3 were recorded. Basal values of 0.2 ng/ml (Perera et al., 1981) and 0.14 ± 0.05 ng/ml (Singh and Madan, 1988) were reached on Days 15–20 and 22 postpartum, respectively.

6. Thyroid hormones

The few studies available on thyroid function in late gestation and early postpartum period in buffaloes adopted different experimental designs. Single blood samples from different groups in various stages of gestation during the same period (1 or 2 months) revealed minor fluctuations of T_4 (thyroxine) levels with no specific trends in Murrah buffaloes (Hung and Prakash, 1990b), but the levels of T_3 (triiodothyronine) and T_4 were reported to decrease in full term (9–10 months) swamp buffaloes (Pichaicharnarong et al., 1982). Variations between individuals and between the two types of buffaloes studied may provide an explanation. Regular sampling from the same buffaloes revealed lower levels of T_3 and T_4 in late gestation in Murrah buffaloes (Khurana and Madan, 1986; Singh et al., 1993) while a distinct rise of protein bound iodine (PBI) was noted in Egyptian buffalo heifers (Hassan and El-Nouty, 1985). In experiments limited to late stages of gestation, Lohan et al. (1989) noted a decrease in T_4 levels during the last 21 days, while a distinct rise of T_3 and T_4 was recorded by Garg et al. (1997) after 271 days until parturition. Differences in climatic conditions prevailing in the last stages of gestation in the different studies may be responsible. A clear drop of T_3, T_4 and PBI at parturition and in the early postpartum period was observed by Hassan and El-Nouty (1985), Lohan et al. (1989), Singh et al. (1993) and Garg et al. (1997). The levels were then increased and became stabilized about 1 month after calving (Pichaicharnarong et al., 1982; Lohan et al., 1989; Bahga, 1989; Bahga and Gangwar, 1989). Resumption of postpartum ovarian activity indicated by follicular growth at 35–42 days (Garg et al., 1997); onset of luteal activity at 43–57 days (Bahga, 1989) or expression of estrus at <45 days (Bahga and Gangwar, 1989) are concomitant with peripheral rise of T_3, T_4 and BPI. Prolonged anestrus was associated with minor fluctuations of T_3 and T_4 levels (Soliman et al., 1981).

7. Postpartum ovarian changes

7.1. Regression of the corpus luteum of pregnancy (corpus albicans)

Postmortem examination of the ovaries of postparturient buffaloes (Agrawal et al., 1979) revealed that the average diameter of the corpus luteum of pregnancy was 3.5 mm on the day of calving and 2 mm 7 days later. None was protruding from the ovarian surface by Day 15.

Palpation per rectum failed to detect corpora albicantia in about one third of the buffaloes on Day 3 and in the majority between Days 15 and 25 (Singh et al., 1979; Deveraj and Janakiraman, 1986). Regression of the corpus luteum of pregnancy was not influenced by either suckling, age or parity (Usmani et al., 1985a, 1990; Honnapagol et al., 1993; Tiwari and Pathak, 1995). Season of calving (Chaudhry et al., 1989) and milk yield (El-Azab et al., 1984) significantly ($P < 0.01$) influenced the time for complete demise of the corpus luteum.

In suckled swamp buffaloes regression of the corpus luteum of pregnancy is very rapid and by Day 10 postpartum it was palpable as a small hard protuberance <3 mm over the ovarian surface (Jainudeen et al., 1983). A mean interval of 7 ± 2 days to complete regression was reported by Momongan et al. (1990).

7.2. Resumption of follicular activity

Negligible follicular development was observed on the ovaries of buffaloes slaughtered on the day of parturition. During the first 15 days postpartum the diameter of the largest follicle was 3–7 mm while it was 7.5–15 mm between Days 30 and 60. The total number of follicles was, however, greater during the first 15 days (Agrawal et al., 1979).

Revival of follicular activity, as detected by rectal palpation, occurred between 15 and 30 days after calving (Singh et al., 1979; Usmani et al., 1985a; Deveraj and Janakiraman, 1986; Bahga and Gangwar, 1988; Chaudhry et al., 1989; Honnapagol et al., 1993) and was independent of the state of uterine involution. Follicles of 8 mm were palpated at an average interval of 21 days in Nili Ravi buffaloes (Usmani et al., 1985b) and were detected earlier in the second (19 days) than in the first lactation (25 days). Anovulatory follicles were reported in postpartum anestrous dairy (El-Wishy, 1979; Usmani et al., 1985b; Barkawi et al., 1986; Abul-Ela et al., 1988; Suthar and Kavani, 1992) and swamp buffaloes (Jainudeen et al., 1983). Restoration of pulsatile LH secretion could be a limiting factor for development and maturation of dominant follicles (Manik et al., 2002).

Follicular activity started 6 days earlier ($P < 0.05$) in the ovaries contralateral to the gravid horn (21 days) than in the ipsilateral (27 days) ovaries (Usmani, 1992) and was higher in the same ovaries during the first 35 postpartum days (Singh et al., 1979).

Suckling (Usmani et al., 1985a; Deveraj and Janakiraman, 1986; Honnapagol et al., 1993; Tiwari and Pathak, 1995), level of milk production (Singh et al., 1979) and prepartum nutrition (Usmani et al., 1990) did not influence the interval to initiation of follicular activity. On the contrary, implications for better development (Tiwari et al., 1993) with large follicles >10 mm diameter were reported to occur earlier (22 days) in nonsuckled than in suckled (30 days) buffaloes (Usmani et al., 1990).

No significant seasonal influences on initiation of follicular development were noted by Singh et al. (1979) and Bahga and Gangwar (1988). Nevertheless, earlier initiation in winter (29 days) than in summer (34 days) calvers and in rainy (January and February) than in dry (December) months calvers (43–48 days viz. 83 days, respectively) were described by Capitan and Takkar (1988) and Ribeiro et al. (2003), respectively. The last-mentioned authors based their findings on increase in ovarian volume as assessed by rectal palpation.

In suckled swamp buffaloes (Jainudeen et al., 1983; Jainudeen, 1984) no follicular activity was detected by rectal palpation during the 1st month after calving but, mature follicles were palpable in the majority of animals (63%) between Days 29 and 56 (mean 40 days). Failure of progesterone to reach normal luteal phase levels in nearly one half of these buffaloes could imply poor luteal development, although anovulation frequently occurring during the postpartum period should not be overlooked.

8. Uterine involution in dairy buffaloes

During the first 24–48 h after calving the gravid uterus is a large flabby sac lying in the abdominal cavity (Chauhan et al., 1977). The average weight of the uterus including the cervix is markedly decreased from about 6 kg just after parturition to about 3 kg on Day 7. On Day 15 when the caruncles are completely degenerated the average weight is 0.7 kg then it decreases to 0.3 kg on Day 45 (Agrawal et al., 1978). The gravid horn becomes located on the pelvic brim by Day 14 (Usmani and Lewis, 1984) then in the pelvic cavity by Days 21–25 (Roy and Luktuke, 1962). Based on anatomical features the uterus of the buffalo is completely involuted by the 45th day postpartum (Agrawal et al., 1978).

Table 1
Distribution of mean uterine involution period in dairy buffaloes

Mean uterine involution period	Number of reports	%
19–21 days (3rd week)	(2)*	4
22–28 days (4th week)	10(2)	24
29–35 days (5th week)	15(2)	36
36–42 days (6th week)	12(2)	30
43–49 days (7th week)	2	4
50–56 days (8th week)	1	2

* Figures in parenthesis indicate number of reports on suckled buffaloes.

The interval from calving to clinically completed involution of the uterus in dairy buffaloes varied widely with a minimum of 15 days (Bhalla et al., 1966) and a maximum of 74 days (Qureshi et al., 1998). The mean values also varied between 19 days (Usmani et al., 1990) and 52 days (Samo et al., 1987). The distribution of 42 mean values (Table 1) recorded in 32 studies included in this review, revealed that 66% were between the 5th and 6th week. Factors such as criteria used for assessing the involution end point, methods of measuring size of the uterus, interval between examinations, climatic and managemental factors in addition to the factors discussed below definitely contribute to the above described spread of values.

Histological studies revealed that normal uterine epithelium was reestablished by 30 days on the nongravid side and 45 days on the gravid side (Agrawal et al., 1978). A mean interval of 35 days was given by Peter et al. (1987).

β-*Haemolitic streptococci*, *Staphylococci epidermidis*, *E. coli*, *Bacillus* spp. and very infrequently *Actinomyces pyogenes* were isolated during the first 2–3 weeks after normal calving but all were completely eliminated by Day 28 postcalving (Singh et al., 1997).

9. Involution of the cervix

Postmortem examination of the cervix revealed a significant ($P < 0.01$) reduction in the external width and thickness up to Day 7 while its length was more rapidly reduced between Days 7 and 15 than between Days 30 and 45. As assessed by rectal palpation involution of the cervix was completed by 24–39 days postpartum (El-Wishy, 1965, 1979; El-Fouly et al., 1976, 1977; Chauhan et al., 1977; Chaudhry et al., 1987; Shah et al., 2004). Gross, histological and histochemical observations revealed that most of the involutionary changes are completed by Day 45 postpartum (Raizada et al., 1978).

10. Factors influencing uterine involution period

10.1. Abnormal parturition

The period required for complete uterine and cervical involution following abnormal parturition such as dystocia, retention of the placenta, abortion and uterine prolapse was 5–14 days longer than in normal cases (El-Wishy, 1965; Chauhan et al., 1977). The nonsignificant difference (41 days viz. 44 days) described by El-Sheikh and Mohamed (1977) can be ascribed to the fact that 12.5% of the assumed normal cases required >51 days for completion of uterine involution. Chauhan et al. (1977) did not find any significant difference in size of the uterus between normal and abnormal calving buffaloes on Days 15 and 45 as assessed by rectal palpation.

Table 2
Relationship between mean uterine involution period and frequency of individual values >40 days

Mean uterine involution period (days)	% of Individual values >40 days	Authors
22	0	Gudi and Deshpande (1977)
26	0	Gudi and Deshpande (1977)
26	8	Usmani and Lewis (1984)
28	11	Chaudhry et al. (1987)
30	2	Bhalla et al. (1966)
35	31	El-Wishy (1965)
35	24	El-Shafie et al. (1983)
37	30	Butchaiah et al. (1975)
38	35	El-Fouly et al. (1976)
39	48	Roy and Luktuke (1962)
40	43	Abul-Ela et al. (1988)
41	45	El-Sheikh and Mohamed (1977)
47	71	El-Fouly et al. (1977)

In cases of dystocia, in addition to the types of bacteria previously mentioned in normal cases, *Proteous* spp., *Klibsiella* spp. and *Staphylococcus aureous* were cultured from a decreasing number of isolates up to 21 days postpartum. On the contrary *A. pyogenes* and *Pseudomonas aeruginosa* persisted up to 35 days in about one half of the cases (Singh et al., 1997). Reports from cattle indicate that when *A. pyogenes* was isolated from uterine fluids after Day 21 postpartum, cows developed severe endometritis and were infertile at first service (Lewis, 1997).

10.2. Subclinical uterine infection

Subclinical uterine infection with delayed uterine involution was reported in 8 out of 62 (13%) normal calving buffaloes (El-Wishy, 1965). A higher frequency of 20–24% was recorded by Ahmad et al. (1985), Khan et al. (1985) and Usmani et al. (2001) who isolated *S. aureous*, *E. coli* and *Proteous vulgaris*. The mean interval to complete uterine involution in such cases (46 ± 5 days) was significantly longer than in normal buffaloes (36 ± 7 days) although diameters of the cervix and uterine horns were not different on Day 12 postpartum and on completion of involution (Usmani et al., 2001).

A study of the breakdown of figures on uterine involution period based on rectal palpation (Table 2) revealed a substantial increase in the frequency of intervals longer than 40 days, i.e. 0–11, 24–35 and 43–71% when the means were 22–30, 35–38 and 39–47 days, respectively. This may justify the use of vaginal inspection as a fundamental part of the routine postpartum genital examination to diagnose subclinical uterine infection. Qureshi et al. (1997) claimed that prepartum injection of Vit. E + selenium as immunopotentiators enhanced uterine involution in buffaloes (28 days viz. 49 days in subclinical uterine infection). Also reduction of the mean uterine involution period to 28 days viz. 35 days in control buffaloes was reported by Ram et al. (1981) following injection of flumethazone (a glucocorticoid) on Days 1 and 8 postpartum.

10.3. Suckling

Usmani et al. (1985a, 1990) reported that uterine involution was accomplished 1 week earlier in limited suckled than in nonsuckled buffaloes. On the other hand no significant effect was noted

by El-Fouly et al. (1976), El-Fadaly (1980), Barkawi (1993), Honnapagol et al. (1993) and Tiwari and Pathak (1995).

10.4. Season and nutrition

No significant seasonal effects on uterine involution period were noted by El-Fouly et al. (1977) and Campo et al. (2002), but significant variations due to month and season of calving were reported by Gudi and Deshpande (1977) and Perera et al. (1987). El-Fouly et al. (1976) and Chauhan et al. (1977) found that winter and spring calvers needed less time for uterine involution than summer and autumn calvers. On the contrary it was claimed that uterine involution was 15 days faster during summer (Bahga et al., 1988a). Heat stress and associated higher levels of cholesterol and PGFM and lower levels of protein bound iodine were implicated (Bahga et al., 1988b; Bahga and Gangwar, 1989). Although injection of exogenous $PGF_2\alpha$, shortly after calving was found to significantly decrease ($P < 0.01$) uterine involution period (El-Fattouh et al., 1990; Nasr et al., 1994; Nazir et al., 1994) no significant effect was noted by Mavi et al. (2004).

The type of ration, i.e. green viz. dry was reported to significantly influence uterine involution period. Buffaloes fed on dry ration during late autumn and early winter had significantly ($P < 0.05$) longer interval (34 ± 2 days) than those (29 ± 1 days) fed green ration (El-Keraby et al., 1981).

Prepartum and postpartum level of nutrition (Usmani et al., 1990), body condition score at parturition (Hegazy et al., 1994) and body weight at parturition (El-Sheikh and Mohamed, 1977) did not significantly influence the period of uterine involution in buffaloes. A significant effect of body weight at parturition was nevertheless, reported by Angulo-Cubillan et al. (1999) in Venezuela.

10.5. Parity

No significant differences between primi- and pluri-parous buffaloes were noted by El-Fouly et al. (1976), El-Sheikh and Mohamed (1977) and Devanathan et al. (1987). Old age at first calving in buffaloes can be accused. The much longer period reported by Chaudhry et al. (1987) for first calvers (39 ± 18 days) compared with older buffaloes (25–27 days) is probably due to uterine infection in some of the few animals studied, as indicated by the very high standard deviation.

Controversy still exists regarding the influence of parity order. Although no significant effects were reported by El-Keraby et al. (1981) and Usmani and Lewis (1984), significant effects were reported by Roy and Luktuke (1962), Chauhan et al. (1977), Deveraj and Janakiraman (1986) and Peter et al. (1987). An increase in the time required with increased parity was reported by the last two authors while no clear trend was noted by the first two authors. Variations in grouping different orders of lactation in the different reports and overlapping of age of buffaloes in different parities can be responsible.

10.6. Milk production

In the very few studies available on the relationship between milk production and uterine involution, a shorter period in low yielding than in high yielding buffaloes was noted by Bahga et al. (1988a) with a difference of 5 days (El-Fadaly, 1980; El-Azab et al., 1984). Nevertheless, no significant effect of level of milk production on that trait was noted by Chauhan et al. (1977) and El-Keraby et al. (1981).

11. Swamp buffaloes

In suckled swamp buffaloes mean intervals of 28 ± 6, 33 ± 3 and 33 ± 4 days for completion of uterine involution were given by Jainudeen et al. (1983), Momongan et al. (1990) and Wongsrikeao et al. (1990), respectively. The latter authors did not find any significant difference in this interval between free suckling and twice daily suckling buffaloes.

12. Relationship between uterine involution period and subsequent reproductive traits

Much controversy exists in the few reports available on the relationship between uterine involution period and postpartum reproductive parameters. Divergence of experimental designs and differences in managerial conditions could be responsible.

12.1. Uterine involution and first postpartum ovulation

Highly significant ($P < 0.01$) correlations ($r = 0.50$ and 0.81) were described by El-Keraby et al. (1981) and Qureshi et al. (1998), respectively, between uterine involution and time to first ovulation. However, nonsignificant correlations ($r = 0.17$ and 0.21) were calculated by El-Sheikh and Mohamed (1977) and Ali Mohamed et al. (1980), respectively.

12.2. Uterine involution and first postpartum estrus

Significant correlations of $r = 0.53$ and 0.41 ($P < 0.01$) between uterine involution period and interval to first estrus were given by Pargaonkar and Kakini (1974) and El-Keraby et al. (1981), while nonsignificant correlations of 0.17, 0.05,0.09, 0.25 and 0.30 were calculated by Bhalla et al. (1966), Chauhan et al. (1977), El-Sheikh and Mohamed (1977), Ali Mohamed et al. (1980) and Suthar and Kavani (1992), respectively.

12.3. Uterine involution and service period

Data from three relevant reports (Table 3) revealed satisfactory fertility in postpartum buffaloes irrespective of the length of the uterine involution period. The main determinant is the interval to postpartum estrus. El-Sheikh and Mohamed (1965), El-Fouly et al. (1977) and Qureshi et al. (1999) reported highly significant correlations of $r = 0.85$, 0.87 and 0.91 ($P < 0.01$), respectively, between the two traits. This means that the interval to postpartum estrus accounts for 72–83% of

Table 3
Uterine involution period and fertility data (means ± S.E.M.)

	El-Fouly et al. (1977)	Usmani et al. (2001)*	El-Wishy, unpublished
Number Of animals	96	22	30
Uterine involution period (days)	47 ± 2	36 ± 1	33 ± 0.4
First ovulation (days)	42 ± 4	34 ± 2	54 ± 5
First estrus (days)	126 ± 7	48 ± 5	82 ± 9
Service period (days)	142 ± 8	65 ± 4	101 ± 12
No. services/conception	1.3	1.7	1.6
Conception rate (%)	77	63	63

* During the first 120 days postpartum.

the variation in length of the service period. So conception readily occurs in postpartum buffaloes once cyclic activity resumes (El-Wishy and El-Sawaf, 1971; Perera et al., 1987). Significant correlations of lower magnitude, i.e. $r = 0.55$ and 0.70 in two herds of Murrah buffaloes (Roy and Luktuke, 1962); 0.42 in Nagpuri buffaloes (Pargaonkar and Kakini, 1974) and 0.23 in Egyptian buffaloes (El-Fouly et al., 1977) were also described.

13. Conclusion

The future fertility of the postpartum buffalo depends upon the rate of uterine involution and resumption of cyclic ovarian activity. In this article literature on endocrinological changes in the peripartum period, initiation of follicular activity after calving and factors affecting uterine involution are reviewed. The role of subclinical uterine infection in protracting the period required for uterine involution needs further consideration. Determination of cervical and uterine horn diameters per rectum is not satisfactory for diagnosis of these cases but vaginal inspection may be a valuable tool in this respect. There is sufficient evidence that follicular activity is resumed early after parturition in the buffalo. However, the factors which initiate maturation and ovulation of these follicles need further investigations. Studies on ultrasonographic assessment of ovarian follicular dynamics together with hormonal profiles (progesterone and LH) are needed to define the circumstances under which early return of cyclic activity can be achieved in the postpartum buffalo.

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