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EFFECTS OF FARROWING INDUCTION ON SOME FARROWING CHARACTERISTICS IN THE PIG − A REVIEW

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Abstract

Several farrowing induction programs have been used to increase the proportion of sow farrowing during the work period and the rate of farrowing supervision, as well as to promote the success of cross-fostering and the practice of all-in all-out in swine production. The present overview aimed to evaluate the effects of farrowing induction on farrowing duration, birth interval, birth weight, dystocia/birth assistance, and stillbirth in pigs. The results showed that via different routes of administration, either natural or synthetic prostaglandins alone or in combination mostly with uterotonic drugs, including oxytocin and carbetocin, have been used for the induction of farrowing. Sometimes other drugs, such as dexamethasone, estradiol, xylazine, ergometrine, and AGN190851, were added. Vulvar and perinatal routes reduced the intramuscular dose of prostaglandins by 50% to 75%, while equal effects remained. A split dose of prostaglandin 6 h apart should be used because it may enhance complete luteolysis. Additionally, if uterotonic drugs are used following prostaglandin injection, they should be injected after the birth of the first piglets at the earliest timepoint to ensure full opening of the cervix. These two practices decrease the farrowing duration, the birth interval, and dystocia. Induction should not be conducted more than 2 days earlier than the expected farrowing date in order to keep the stillbirth rate and birth weight unaltered. This review also revealed that certain factors, such as the rate of farrowing supervision, natural differences in piglets' birth weights, litter size, gestation length, and treatment with altrenogest before induction, may be confounding factors that possibly alter the effect of induction programs on certain farrowing characteristics.

Key words: pig, farrowing induction, cloprostenol, dinoprost, stillbirth

After decades of genetic selection, improvement of management, and nutrition science, the reproductive performance of the pig has increased considerably (Koketsu et al., 2017), and the litter size may exceed the number of functional teats. In such cases, if piglets are not cross-fostered to another litter, their survival rate is decreased (Calderón Díaz et al., 2018; Kirkwood, 2015). Moreover, an increase in litter size results in an elevated stillbirth rate (Borges et al., 2005; Nam and Sukon, 2020 a) which was recently reported to vary between 5 and 8% when the litter size was from 13.2 to 15.1 (Boonraungrod et al., 2018; Nam and Sukon, 2020 a, 2021, 2022 a; Taechamaeteekul et al., 2022). Therefore, the stillbirth rate is expected to increase because the number of piglets born per sow per year has been forecasted to reach 40 in the future (Koketsu et al., 2017). The stillbirth rate also increases in cases of a decreased farrowing supervision rate (Le Cozler et al., 2002), which particularly occurs during the weekend. The supervision of farrowing and the cross-fostering of piglets can only be applied if sows farrow during the work period and in a synchronous program.

Farrowing induction has been applied to reduce the variation in gestation length, to increase the proportions of sow farrowing during the work period and to enhance the chance of timely cross-fostering, thereby increasing piglet survivability and the uniformity of weaning days (Calderón Díaz et al., 2018; Kirkwood, 2015). Farrowing can be induced with natural prostaglandin or with its synthetic analogs alone or in combination with uterotonic drugs such as oxytocin and carbetocin (Boonraungrod et al., 2018; Cassar et al., 2005; Mills et al., 2021; Tospitakkul et al., 2019). Prostaglandins are used as a single dose (Mills et al., 2021) or a split dose (Gunvaldsen et al., 2007; Tospitakkul et al., 2019), and uterotonic drugs are generally used 24 h after prostaglandin injection to increase the synchrony of farrowing (Boonraungrod et al., 2018; Decaluwé et al., 2014; Mills et al., 2021). Additionally, the initial time of the induction program might vary among studies. All of these variations may produce different effects on farrowing characteristics. Moreover, some factors other than farrowing induction may influence the results. Very recently, a systematic review (Monteiro et al., 2021) concluded that the stillbirth

rate was significantly reduced when an injection of prostaglandins was conducted one day prior to the expected farrowing date. However, only two studies included in their analysis showed a reduction in the stillbirth rate, one study of which had different management practices (Nguyen et al., 2011).

Farrowing induction influences sow hormones and thereby influences the parturition process. A successful induction program should not impair farrowing characteristics. This overview aims to investigate the effects of farrowing induction programs on birthing traits, including farrowing duration, birth interval, birth weight, stillbirth rate, and dystocia/birth assistance in pigs. Additionally, this paper addresses some potential confounding factors that might alter the findings on the effects of farrowing induction on certain farrowing characteristics. The study designs and main outcomes of each cited reference included in this review are summarized in Table 1.

Table 1. Study designs and main outcome of cited references

Study characteristics/Authors	Main outcomes
1	2
Vietnam, Landrace × Yorkshire, parity=3.9; Treatment: A single dose of 175 µg cloprostenol at the vulva, Day 114, litter size=14.0, n=20; Control: natural farrowing, n=18, litter size=15.0 (Nam et al., 2022)	Farrowing induction did not alter the stillbirth rate (6.8 vs. 7.4%), farrowing duration (284 vs. 210 minutes), or birth weight (1417 vs. 1436 g), but increased the birth interval (22 vs. 15 minutes) and dystocia at both sow (90 vs. 50%) and piglet levels (11.5 vs. 6.3%)
Thailand, Landrace × Yorkshire, parity=3.1, intramuscular injection of prostaglandin. Treatment 1: 20 mg altrenogest per day from Day 107 (105−108) + (180 µg cloprostenol + 180 µg cloprostenol, 6 h apart, Day 114), litter size=15.4; Treatment 2: 20 mg altrenogest per day from Day 107 (105−108) + (180 µg cloprostenol + 180 µg cloprostenol, 6 h apart, Day 115), litter size=15.1; Treatment 3: 20 mg altrenogest per day from Day 107 (105−108) + (180 µg cloprostenol + 180 µg cloprostenol, 6 h apart, Day 116), litter size=14.1; Control: natural farrowing, n=94, litter size=14.5 (Taechamaeteekul et al., 2022)	Farrowing induction increased the stillbirth rate (5.8, 16.4, 17.2, and 11.8%, respectively). There was a significant increase in the proportion of litters that had ≥3 stillbirths in the altrenogest/cloprostenol groups compared with that in the control (24.5 vs. 5.3%). There was decreased birth weight in the group induced at Day 113 of gestation in comparison with the control group and the groups induced at Days 114 and 115 (1.22 vs. 1.40, 1.49, and 1.42 kg, respectively)
USA, breeds and parity were not reported, intramuscular prostaglandin injection in the neck; subcutaneous oxytocin injection in the crease between the vulva and the ham. Treatment 1: 10 mg dinoprost tromethamine Day 114 + 10 IU oxytocin 24 h later, n=13, litter size=13.8; Treatment 2: 10 mg dinoprost tromethamine Day 114 + (5 IU oxytocin + 5 IU oxytocin, 6 and 12 h later), n=21, litter size=12.9; Control: natural farrowing, n=24, litter size=13.2 (Mills et al., 2021)	No effect on farrowing duration (285.6, 231.6, and 213 min), stillbirths (5, 5.9 and 5.4 min), and the dystocia rate (13.8, 14.9, and 13.3%) was found. Farrowing induction increased the colostrum lactose concentration. There was decreased birth weight in the group receiving a single dose of oxytocin as compared with the control and induced group receiving double doses of oxytocin (1.30 vs. 1.35, and 1.43 kg, respectively)
Thailand, Landrace × Yorkshire, parity=2.15, Treatment 1: 184 µg cloprostenol, intramuscular route, Day 114, n=32, litter size=12.3; Treatment 2: 92 µg cloprostenol + 92 µg cloprostenol, intravulvosubmucosal route, 6 h apart, Day 114, n=23, litter size=13.6; Control: natural farrowing, n=36, litter size=13.4 (Tospitakkul et al., 2019)	There was an increased farrowing duration (241.1 vs. 190.3 and 169.5 min) and birth interval in the single dose of cloprostenol (20.1 vs. 14.6 and 13.3 min) group and a decreased dystocia rate in the double dose (2.7 vs. 11.8 and 10.6%) group. No effect on the stillbirth rate (8.8, 9.8, and 11.7%) and birth weight (1.29, 1.30, and 1.26 kg) was found
Australia, Large White × Landrace. Vulvar injection of prostaglandin, with intramuscular injection of oxytocin and carbetocin. Treatment 1: 200 µg cloprostenol (100 + 100, 6 h apart) 2 days before the expected farrowing date + 10 IU oxytocin after the birth of the first piglet, parity=2.3, litter size=12.9, n=35; Treatment 2: 200 µg cloprostenol (100 + 100, 6 h apart) 2 days before the expected farrowing date + 0.07 mg carbetocin after the birth of the first piglet, parity=2.4, litter size=13.3, n=36; Control: 200 µg cloprostenol (100 + 100, 6 h apart) 2 days before the expected farrowing date, n=30, parity=2.7, litter size=13.2 (Ward et al., 2019)	Both induction programs reduced the farrowing duration (179.8, 155.9, and 243.5 minutes), but they did not alter the dystocia rate per farrow (1.1, 0.8, and 1) or the number of stillbirths per litter (0.5, 0.7, and 0.7 piglets)
Thailand, Landrace × Yorkshire, intramuscular injection of prostaglandin and carbetocin. Treatment 1: 175 µg cloprostenol, Day 114, n=50, parity=2.0, litter size=13.3; Treatment 2: 175 µg cloprostenol Day 114 + 0.3 µ/kg carbetocin 24 h later, n=53, parity=2.1, litter size=13.5; Control: natural farrowing, n=80, parity=2.2, litter size=13.5 (Boonraungrod et al., 2018)	There was no effect on the farrowing duration (294, 259, and 289 min), birth interval (20.7, 19.3, and 17.1), and stillbirth rate (4, 4.7, and 6.1%). An increased assistance rate in the cloprostenol plus carbetocin group (50, 73.6, and 33.8%) was observed. There was a decreased birth weight in the group receiving carbetocin in comparison with the control and cloprostenol alone groups (1.46 vs. 1.52 and 1.51 kg, respectively)
USA, Landrace × Yorkshire, parity=1−4, litter size not reported. Treatment: 250 µg cloprostenol, route not reported, Day 114, n=88; Control: natural farrowing, n=86 (Vallet and Miles, 2017)	No effect on the farrowing duration, birth weight, and stillbirth rate was found
Brazil, Camborough 25, parity=4.6. Treatment: vulvar submucosal injection of 175 µg cloprostenol, Day 114, n=48, litter size=12.5; Control: natural farrowing, n=48, litter size=13.2 (Otto et al., 2017)	No effect on the farrowing duration (197 vs. 216 min), stillbirth rate (4.7 vs. 5.5), and birth weight (1.40 vs. 1.39 kg) was found

Table 1. – contd.

1	2
Germany, Large White × Landrace, parity not reported, intramuscular injection of prostaglandin, oxytocin, and carbetocin. Treatment 1: 175 µg cloprostenol, Day 114, n=719, litter size=11.7; Treatment 2: 175 µg cloprostenol Day 114 + 20 IU oxytocin 24 h later, n=180, litter size=10.8; Treatment 3: 175 µg cloprostenol Day 114 + 70 µg carbetocin 24 h later, n=175, litter size=10.3; Treatment 4: 175 µg cloprostenol Day 114 + 35 µg carbetocin 24 h later, n=191, litter size=10.6. Control: natural farrowing, n=710, litter size=12.0 (Zaremba et al., 2015)	No effect on the farrowing duration (230, 209, 186, 184, and 240 min) or birth interval (21, 21, 19, 19, and 21 min) was found. The dystocia rate at the farrowing level was different among the induction programs (21, 19.8, 11.4, 13.8, and 12.3%)
India, Duroc, parity 1−2. Treatment: intramuscular injection of 526 µg cloprostenol Day 114, n=13, litter size=6.1; Control: natural farrowing, n=17, litter size=4.8 (Gokuldas et al., 2015)	Farrowing induction decreased the farrowing duration (190 vs. 263 min) and the stillbirth rate (8.0 vs. 24.4%). There was a lower birth weight in the control group (1.05 vs. 1.60 kg)
Belgium, Topigs 20, intramuscular injection of prostaglandin and oxytocin in the neck. Treatment 1: 2 mg alfaprostol, Day 114, n=26, parity=3, litter size=14.6; Treatment 2: 2 mg alfaprostol Day 114 + 10 IU oxytocin, 24 h later, n=28, parity=3, litter size=15.3; Treatment 3: (1 mg + 1 mg) alfaprostol, 6 hours apart, Day 114, n=28, parity=4, litter size=15.8; Control: natural farrowing, n=29, parity=3, litter size=15.4 (Decaluwé et al., 2014)	No effect on the farrowing duration (183, 194, 193, and 186 min), birth interval (13, 13, 15, and 14 min), stillbirth rate (2.3, 5.7, 0, and 5.9), dystocia rate (1, 1, 0, and 1 per litter), or birth weight (1.2, 1.2, 1.3, and 1.3 kg) was observed
Brazil, Landrace 9 Duroc/Large White, parity 3−5, vulvosubmucosal injection of prostaglandin. Treatment 1: 5 mg cloprostenol, Day 114, n=52, parity=4.0, litter size=12.6; Treatment 2: 20 mg altrenogest, n=51, natural farrowing, parity=4.0, litter size=12.3; Treatment 3: 20 mg altrenogest Day 111−113 + 5 mg cloprostenol, Day 114, n=50, parity=4.0, litter size=12.5; Control: natural farrowing, n=55, parity=4.3, litter size=11.6 (Gaggini et al., 2013)	No effect on the farrowing duration (240, 282, 246, and 258 min), stillbirth rate (4.5, 6.5, 5.6, and 3.4%), or birth weight (1536, 1535, 1547, and 1561 g) was observed
USA, Genetiporc F20, parity 1−2, intramuscular injection of prostaglandin and oxytocin. Treatment 1: 7.5 mg dinoprost tromethamine, Day 113, n=155, litter size=12.1; Treatment 2: 7.5 mg dinoprost tromethamine, Day 114, n=158, litter size=12.6; Treatment 3: 7.5 mg dinoprost tromethamine, Day 116, n=156, litter size=12.9. Sows that did not farrow after 22−24 h received 10 IU oxytocin (Smith et al., 2013)	The number of stillbirths per litter (0.52, 0.74, and 0.78) was not different among groups
Thailand, parity 1, intramuscular injection of prostaglandin and oxytocin. Treatment 1: 175 µg cloprostenol Day 113, + 20 IU oxytocin 24 h later, n=20, litter size=11.8; Control: natural farrowing, n=20, litter size=13.35 (Leethongdee et al., 2012)	There was a decreased number of stillbirths per litter (0.05 vs. 0.35%). The birth weight was unaltered by treatment (1.30 vs. 1.37 kg)
Bulgaria, PIC sows, parity=4.9, intramuscular prostaglandin injection. Treatment 1: 2 mg alfaprostol, Day 111−112, n=29, litter size=11.44; Treatment 2: 2 mg alfaprostol, Day 113−114, n=54, litter size=13.09; Treatment 3: 2 mg alfaprostol, Day 115, n=12, litter size=11.83 (Dimitrov et al., 2012)	There was no effect on the number of stillbirths per litter (0.73, 0.65, and 0.49)
Canada, Yorkshire × Landrace. Intravulvar injection of prostaglandin. Treatment 1: 5 mg dinoprost tromethamine + 5 mg dinoprost tromethamine, 6 h apart, Day 114, n=75, parity=6.4, litter size=11.8; Control: natural farrowing, n=84, parity=5.5, litter size=12.3 (Nguyen et al., 2011)	There was a decreased number of stillbirths per litter (0.4 vs. 1)
France, Landrace × Large White, gilts. Treatment: 2 mg alfaprostol, intramuscular injection, Day 113, n=9, litter size=12.3; Control: natural farrowing, n=11, litter size=11.4 (Foisnet et al., 2011)	No effect on the farrowing duration (176 vs. 162 min) or birth weight (1.23 vs. 1.34 kg) was found
Canada, Landrace and Large White, injection of prostaglandin in external abdominal oblique muscle, litter size=14.9. Treatment 1: 87.5 µg cloprostenol + 87.5 µg cloprostenol, 7 h apart, Day 113−114, n=131; Control: natural farrowing, n=85 (Olson et al., 2009)	There was no effect on the stillbirth rate. Decreased birth weight (107 g per piglet) was observed
Canada, PIC. Treatment 1: 87.5 µg cloprostenol + 87.5 µg cloprostenol, 6 h apart, vulva, Day 114, n=39, parity=3.5, litter size=12.3; Treatment 2: 87.5 µg cloprostenol + 87.5 µg cloprostenol, 6 h apart, external abdominal oblique muscle, Day 114, n=36, parity=3.5, litter size=12.2; Control: natural farrowing, n=36, parity=3.2, litter size=11.1 (Gunvaldsen et al., 2007)	There was no effect on the stillbirth rate (5.4, 7.1, and 5.2%) but a significant effect on the birth weight (1.53, 1.56, and 1.68 kg)
Thailand, Landrace × Yorkshire, parity=4.7. Treatment 1: Intramuscular injection of 75 µg cloprostenol Day 113−114, n=10, litter size=12.6; Treatment 2: intramuscular injection of 75 µ cloprostenol Day 113−114 + 10 IU oxytocin 24 h later, n=10, litter size=9.3; Treatment 3: perivulvar injection of 37.5 µg cloprostenol Day 113−114, n=10, litter size=10.9; Treatment 4: perivulvar injection of 37.5 µg cloprostenol Day 113−114 + 10 IU oxytocin 24 h later, n=10, litter size=13.7; Control: natural farrowing, n=10, litter size=12.3 (Kaeoket, 2006)	There was no effect on the farrowing duration (390, 297, 275, 301, and 246 min), birth interval (23, 34, 23, 22, and 18 min), stillbirth rate (3.2, 1.1, 3.4, 10.2, and 6.5%), or birth weight (1.6, 1.6, 1.5, 1.4, and 1.5 kg)

Table 1. – contd.

1	2
Canada, vulvar injection of prostaglandin and intramuscular injection of dexamethasone and oxytocin into the neck. Experiment 1: Treatment 1: 2.5 or 5 mg dinoprost tromethamine + (2.5 or 5 mg dinoprost tromethamine + 20 mg dexamethasone) Day 113, 6 h apart, n=41, litter size=11.5; Treatment 2: 2.5 or 5 mg dinoprost tromethamine + 2.5 or 5 mg dinoprost tromethamine Day 113, 6 h apart, n=43, litter size=10.8 Experiment 2: Treatment 1: 5 mg dinoprost tromethamine, Day 113, n=29, parity=6.4, litter size=11.7; Treatment 2: 5 mg dinoprost tromethamine Day 113 + 20 IU oxytocin 24 h later, n=28, parity=8.1, litter size=10.5; Treatment 3: 2.5 mg dinoprost tromethamine + 2.5 mg dinoprost tromethamine, 6 h apart, Day 113, n=24, parity=8.4, litter size=12.0; Treatment 4: 2.5 mg + 2.5 dinoprost tromethamine, 6 h apart Day 113 + 20 IU oxytocin 24 h after the 1st prostaglandin injection, n=25, parity=8.4, litter size=10.6 (Cassar et al., 2005)	Experiment 1: The two induction programs had similar effects on the farrowing duration (180 vs. 162 minutes), stillbirth rate (4.3 vs. 5.3%), and birth weight (1.52 vs. 1.49 kg). Experiment 2: The four induction programs had similar effects on the farrowing duration (186, 162, 168, and 156 minutes), stillbirth rate (8.1, 7.8, 8.5, and 7.6%), and proportions of sows needing birth assistance (47.1, 81.0, 57.1, and 65.0%)
Italy, Landrace × Yorkshire, prostaglandin and dexamethasone were injected into the vulva and neck, respectively. Treatment 1: 1/2 dose luprostiol, Day 113; n=24, litter size=10.2; Treatment 2: 1/2 dose luprostiol + 1/2 dose luprostiol, 6 h apart, Day 113, n=26, litter size=11.7; Treatment 3: 1/2 dose luprostiol + 20 mg dexamethasone 6 h later, Day 113, n=25, litter size=10.2; Treatment 4: 1/2 dose luprostiol + (1/2 dose luprostiol + 20 mg dexamethasone) 6 h later, Day 113, n=31, litter size=11.2 (De Rensis et al., 2002)	The farrowing duration (120, 154, 127, and 153 min), birth interval (11, 14, 13, and 14 min), and birth weight (1.52, 1.50, 1.46, and 1.45 kg) were not different among the induction groups
Canada, Landrace × Yorkshire, prostaglandin and oxytocin were injected intramuscularly. Experiment 1: Treatment 1: 175 µg cloprostenol, Day 113, n=49, litter size=11.9; Treatment 2: 175 µg cloprostenol + 175 µg cloprostenol, 6 h later, Day 113, n=54, litter size=11.9. Experiment 2: Treatment 1: 175 µg cloprostenol, Day 113, n=59, litter size=11.4; Treatment 2: 175 µg cloprostenol + 175 µg cloprostenol 6 h later, Day 113, n=48, litter size=11.7; Treatment 3: 175 µg cloprostenol + 30 IU oxytocin 6 h later, Day 113, n=56, litter size=12.5 (Kirkwood and Aherne, 1998)	Experiment 1: Single and double treatment had similar effects on the stillbirth rate (3.4 vs. 5.0%). Experiment 2: The three induction programs had similar effects on the stillbirth rate (3.5, 7.7, and 5.6%)
Greece, Large White × Landrace, parity 2−5, prostaglandin, oxytocin, and NaCl 0.9% (placebo) were injected intramuscularly. Control 1: placebo Day 111 + placebo Day 112, n=20, litter size=11.25; Control 2: placebo Day 112 + placebo Day 113, n=20, litter size=11.40; Control 3: placebo Day 113 + placebo Day 114, n=20, litter size=11.15; Treatment 1: cloprostenol 175 Day 111 + placebo Day 112, n=20, litter size=11.10; Treatment 2: cloprostenol 175 Day 112 + placebo Day 113, n=20, litter size=11.15; Treatment 3: cloprostenol 175 Day 113 + placebo Day 114, n=20, litter size=11.25; Treatment 4: cloprostenol 175 Day 111 + oxytocin 10 IU Day 112, n=20, litter size=11.25; Treatment 5: cloprostenol 175 Day 112 + oxytocin 10 IU Day 113, n=20, litter size=11.20; Treatment 6: cloprostenol 175 Day 113 + oxytocin 10 IU Day 114, n=20, litter size=11.00 (Alexopoulos et al., 1998)	Farrowing induction at Day 111 increased farrowing duration (3.7, 4.45, and 4.65 h), rate of manual assistance (5, 20, and 40%), and number of stillbirths per litter (1, 1.75, and 2.05 piglets). In contrast, farrowing duration at Days 112 and 113 did not influence farrowing duration (3.55, 3.95, and 3.9 h; and 3.95, 3.75, and 3.55 h), rate of manual assistance (5, 10, and 20%; and 10, 5, and 10%), and number of stillbirths per litter (1.35, 1.50, and 1.65; and 1.20, 1.35, and 0.75 piglets)
USA, Landrace × Yorkshire, parity=5.2, the litter size of each group was not mentioned, prostaglandin, oxytocin, AGN 190851, and saline were intramuscularly injected. Treatment 1: 10 mg dinoprost tromethamine Day 111 + 30 IU oxytocin 24 h later, n=20; Treatment 2: 10 mg dinoprost tromethamine Day 111 + 0.06 mg/kg AGN 190851 20 h later, n=20; Treatment 3: 10 mg dinoprost tromethamine Day 111 + 0.1 mg/kg AGN 190851 20 h later, n=20; Control: Saline − Saline, 20 h apart, n=20 (Yang et al., 1996)	No effect on the farrowing duration (270, 252, 246, and 258 min) was observed. There was a decreased stillbirth rate in the dinoprost + 0.1 mg/kg AGN 190851 (3.9%) and control (7%) groups compared with the dinoprost + oxytocin (18.3%) and dinoprost + 0.06 mg/kg AGN 190851 (12.1%) groups
USA, multiparous sows, prostaglandin, xylazine, and saline were intramuscularly injected, Treatment 1: 250 µg cloprostenol Day 112 + 1 ml saline 20 h later, n=20, litter size=10.9; Treatment 2: 1 ml saline Day 112 + 2 mg/kg xylazine 20 h later, n=20, litter size=10.3; Treatment 3: 250 µg cloprostenol Day 112 + 2 mg/kg xylazine 20 h later, n=20, litter size=10.6; Control: 1 ml saline Day 112 + 1 m saline 20 h later, n=20, litter size=9.8 (Ko et al., 1989)	No effect on the farrowing duration (300, 312, 270, and 318 min) or stillbirth rate (7.3, 7.0, 6.6, and 5.2%) was found
Australia, Large White, the drug route was not reported. Treatment 1: 175 µg cloprostenol, Day 113, n=42, parity=2.7, litter size=11.6; Treatment 2: 175 µg cloprostenol + 0.75 mg ergometrine after the birth of the 1st piglet, Day 113, n=33, parity=2.7, litter size=10.6; Treatment 3: 175 µg cloprostenol Day 113 + 30 IU oxytocin after the birth of the 1st piglet, n=30, parity=2.1, litter size=10.5; Control: natural farrowing, n=37, parity=2.9, litter size=10.5 (Stone et al., 1987)	There was no effect on the stillbirth rate (4.3, 5.7, 6.7, and 9.5%) or birth weight (1.5, 1.7, 1.5, and 1.5 kg)

Table 1. – contd.

1	2
USA, the breed was not reported, gilts and sows. Prostaglandin, oxytocin, estradiol benzoate, and saline were injected intramuscularly. Experiment 1: prostaglandin was injected into the ham muscle, litter size=9.7−10.6. Treatment 1: 2.5 mg dinoprost tromethamine Day 111−113, n=32; Treatment 2: 5 mg dinoprost tromethamine Day 111−113, n=32; Treatment 3: 10 mg dinoprost tromethamine Day 111−113, n=34; Treatment 3: 20 mg dinoprost tromethamine Day 111−113, n=30; Control: natural farrowing, n=25. Experiment 2: Treatment 1: 10 mg dinoprost tromethamine Day 111−113, n=49; Control: vehicle injection, natural farrowing, n=22. Experiment 3: Treatment 1: 10 mg dinoprost tromethamine Day 111−113, n=9; Treatment 2: 10 mg dinoprost tromethamine Day 111−113 + 40 IU oxytocin 24−28 h later, n=14. Experiment 4: Treatment 1: 10 mg dinoprost tromethamine Day 111−113 + 40 IU oxytocin 24 h after $PGF_{2\alpha}$, n=25; Treatment 2: 10 mg dinoprost tromethamine Day 111−113 + 5 mg estradiol benzoate 6 h later + 40 IU oxytocin 24 h after $PGF_{2\alpha}$, n=28; Control: injection of saline, natural farrowing, n=18 (Gall and Day, 1987)	Experiment 1: Farrowing induction did not affect the birth weight (1.5, 1.5, 1.4, 1.4, and 1.4 kg), number of stillbirths per litter (0.6, 0.7, 0.9, 1.0, and 0.7 piglets), or farrowing duration (162, 252, 240 144, and 204 minutes). Experiment 2: Farrowing did not affect the farrowing duration (216 vs. 168 minutes). Experiment 3: There was no difference in the stillbirth rate or farrowing duration (150 vs. 174 minutes) between the 2 groups. Experiment 4: Farrowing induction had no effect on the farrowing duration (2.4, 2.7, and 3.3 h), birth weight (1.4, 1.0, and 1.4 kg), and number of stillbirths per litter (0.7, 1.3, and 0.9 piglets)
Thailand, Landrace × Yorkshire, prostaglandin, oxytocin, and placebo were injected intramuscularly into the neck. Treatment 1: 10 mg dinoprost tromethamine Day 112 + placebo 20 h later, n=10, litter size=6.8; Treatment 2: 10 mg dinoprost tromethamine Day 112 + 10 IU oxytocin 20 h later, n=10, litter size=11.3; Treatment 3: 10 mg dinoprost tromethamine Day 112 + 20 IU oxytocin 20 h later, n=10, litter size=9.5; Treatment 4: 10 mg dinoprost tromethamine Day 112 + 30 IU oxytocin 20 h later, n=10, litter size=9.1; Treatment 5: placebo Day 112 + 30 IU oxytocin 20 h later, n=10, litter size=10.7; Control: placebo Day 112 + placebo 20 h later, natural farrowing, n=10, litter size=8.8 (Chantaraprateep et al., 1986)	No effect on the stillbirth rate (5.7, 6.9, 3.2, 2.2, 1.9, and 10.2%), assistance rate in sows (10, 0, 50, 30, 30, and 0%), or birth weight (1.6, 1.5, 1.6, 1.4, 1.5, and 1.4 kg) was observed
Canada, Yorkshire, multiparous sows, Treatment 1: 175 µg cloprostenol in ham muscle Day 113, n=51, litter size=11.3; Treatment 2: 125 µg cloprostenol in ham muscle Day 113, n=57, litter size=11.0; Control: saline Day 113, natural farrowing, n=53, litter size=10.8 (Fraser and Connor, 1984)	Farrowing induction had no effect on the stillbirth rate (7.7, 6.3, and 8.2%)
New Zealand, Landrace × Yorkshire, mainly in 4−7 parity. Treatment 1: intramuscular injection of 10 mg dinoprost tromethamine, Day 112−113, n=19, litter size=12.9; Control: Natural farrowing, n=19, litter size=12.6 (Smith et al., 1982)	Farrowing induction increased the farrowing duration (390 vs. 246 min) but did not alter the number of stillbirths per litter (0.6 vs. 0.8 piglets) or the birth weight (1.34 vs. 1.37 kg)
England, parity, breeds, and route of injection were not reported, Treatment 1: 175 µg cloprostenol Day 114, n=19, litter size=10.7; Treatment 2: 1 mg alfaprostol, Day 114, n=16, litter size=10.7; Treatment 3: 2 mg alfaprostol Day 114, n=17, litter size=12.1; Treatment 4: 3 mg alfaprostol Day 114, n=16 litter size=9.6; Control: natural farrowing, n=19, litter size=10.2 (Boland and Herlihy, 1982)	No effect on the number of stillbirths per litter (0.9, 1.3, 2.4, 0.8, and 1.1 piglets) or the birth weight (1.30, 1.27, 1.20, 1.12, and 1.16 kg) was found
USA, Landrace, parity 2−4, intramuscular injection of prostaglandins. Experiment 1: Treatment 1: 2−3 mg alfaprostol, n=130, litter size=10.37. Treatment 2: 175 cloprostenol Day 112, n=125, litter size=10.79. Control: natural farrowing, n=248 was divided into 2 subgroups, litter size=10.50. Experiment 2: Treatment 1: 2 mg alfaprostol Day 112, n=240; Control: natural farrowing, n=240. The treatment and control groups were divided in 4 subgroups conducted in 4 seasons. The corresponding treatment-control subgroups' litter sizes were 11.03 vs. 10.74; 10.98 vs. 10.17; 10.84 vs. 11.03; and 10.13 vs. 10.42 (Cerne and Jöchle, 1981)	Experiment 1: Farrowing induction decreased the number of stillbirths per litter (0.34, 0.22 vs. 0.65–0.77 piglets) but had no effect on the farrowing duration (243, 236, 267, and 272 minutes). Experiment 2: Farrowing induction decreased the number of stillbirths per litter (0.39 vs. 0.97; 0.56 vs. 1.32; 0.49 vs. 1.26; and 0.70 vs. 1.03 piglets) and had no effect on the birth weight (1.29 vs. 1.68; 1.38 vs. 1.64; 1.50 vs. 1.55; and 142 vs. 1.57 kg) or farrowing duration (260 vs. 250; 225 vs. 290; 285 vs. 270; and 255 vs. 305 minutes)

Methods of induction

Farrowing in swine may be induced between Days 111 and 115 of gestation (Cassar et al., 2005; Hernandez et al., 2009; Taechamaeteekul et al., 2022; Tospitakkul et al., 2019); a majority of recent studies started the program on Day 114 (Boonraungrod et al., 2018; Hlavová et al., 2020; Mills et al., 2021; Nam et al., 2022; Tospitakkul et al., 2019; Vallet and Miles, 2017). Induction on Day 114 has been shown to reduce the harmful effect of short gestation length on stillbirth (Nam and Sukon, 2020 b, 2021), as most sows farrow on Days 114–116.

Both natural (dinoprost) and synthetic (alfaprostol, cloprostenol, luprostiol) prostaglandins have been used for farrowing induction (Decaluwé et al., 2014; De Rensis et al., 2002; Mills et al., 2021; Nam et al., 2022). Among the prostaglandins used, cloprostenol is the most popular, with the most frequently reported dose of 175 µg (Boonrondraud et al., 2018; Nam et al., 2022; Otto et al., 2017; Zaremba et al., 2015). Some authors have used a lower dose of 37.5 µg or 75 µg (Kaeoket et al., 2006), 125 µg (Fraser and Conor, 1984), or a higher dose of 250 µg (Vallet and Miles, 2017), 370 µg (Taechamaeteekul

et al., 2022), 526 µg (Gokuldas et al., 2015) or even 5000 µg (Gaggini et al., 2013). The reported dose of 5000 µg by Gaggini et al. (2013) is surprising because it exceeded the 175 µg manufacturer's recommended dose (Sincrocio®, Ourofino) and it did not affect any investigated parameters including farrowing duration, birth weight, and stillbirth. Dinoprost is the second most commonly used prostaglandin, with a dose ranging between 2.5 and 20 mg and a most frequently reported dose of 10 mg (Gall and Day, 1987; Mills et al., 2021; Nguyen et al., 2011). Alfaprostol is sometimes used at a dose ranging between 1 and 3 mg (Decaluwé et al., 2014; Dimitrov et al., 2012; Foisnet et al., 2011).

Prostaglandins are usually injected intramuscularly into the neck of sows; however, some authors have also administered hormones into the vaginal mucosa (Kirkwood et al., 1996), vulva (Gaggini et al., 2013; Gunvaldsen et al., 2007; Nam et al., 2022; Otto et al., 2017), perianal region (Kirkwood et al., 1996; Mills et al., 2021), and abdominal region (Gunvaldsen et al., 2007; Olson et al., 2009). Different routes of administration might result in a difference in time for absorption and effect. The doses for vulvar and perianal administration were suggested to be 25% and 50%, respectively, of the dose for intramuscular injection to produce similar effects (Kirkwood et al., 1996). Commonly, farrowing is induced with a single administration of a prostaglandin (Boonraungrod et al., 2018; Nam et al., 2022; Otto et al., 217; Vallet and Miles, 2017), but complete luteolysis is suspected with this single treatment (Tospitakkul et al., 2019). Recently, some authors used a split dose (1/2 + 1/2 dose) (Tospitakkul et al., 2019) and a double dose (1 + 1 dose) (Taechamaeteekul et al., 2022) because this might increase the completion of luteolysis, and the beneficial effects of the split dose against a single dose on birth interval and farrowing assistance were approved (Tospitakkul et al., 2019). The use of a double dose could also increase the rate of sow farrowing during working hours (Kirkwood and Adherne, 1998).

Although prostaglandins could synchronize farrowings, many sows continue to farrow outside of working hours. Therefore, uterotonic drugs such as oxytocin and carbetocin were added to the induction program to increase the synchrony of farrowings (Kirkwood and Adherne, 1998; Boonraungrod et al., 2018). The percentage of sows farrowing during working hours increased from 61 to 84% and 66% to 98% when oxytocin (Kirkwood and Adherne, 1998) and carbetocin (Boonraungrod et al., 2018), respectively, were added to the induction programs. In many programs, oxytocin is injected 24 h after the administration of prostaglandins, and this practice might reduce the farrowing duration but also increase the stillbirth rate and farrowing dystocia/assistance (Kirkwood, 2015; Muro et al., 2021). Other drugs, such as dexamethasone (Cassar et al., 2005; De Rensis et al., 2002), estradiol benzoate (Gall and Day, 1987), xylazine (Ko et al., 1989), and ergometrine (Stone et al., 1987), could also be added to the induction programs with no effects on farrowing characteristics, including farrowing duration, birth interval, birth weight, stillbirth rate, and dystocia/birth assistance.

Farrowing duration and birth interval

Most studies have shown that farrowing induction does not influence the farrowing duration (Boonraungrod et al., 2018; Decaluwé et al., 2014; Foisnet et al., 2011; Gaggini et al., 2013; Nam et al., 2022; Otto et al., 2017). A few authors found that farrowing duration is increased in induced sows (Tospitakkul et al., 2019; Smith et al., 1982). Smith et al. (1982) used 10 mg dinoprost tromethamine on Days 112−113 and found that the farrowing duration was longer in the induced group (390 minutes) than in the control group (246 minutes) ($P<0.05$). Tospitakkul et al. (2019) used cloprostenol on Day 114 and reported that the single full dose of 184 µg increased the farrowing duration when compared to a split dose (92 µg × 2, 6 h apart) and the control (241, 190, and 170 minutes, respectively). The negative effect of farrowing induction with a single full dose of 184 µg cloprostenol on farrowing duration in that study (Tospitakkul et al., 2019) was more pronounced when considering the lower litter size in this group than in the two other groups (12.3 vs. 13.6 and 13.4) because litter size is positively associated with farrowing duration (Nam and Sukon, 2020 a; van Dijk et al., 2005). The day of gestation on which the sows were induced might be another factor that influences the effect of induction on farrowing duration. In a study that induced farrowing on Days 111, 112 or 113 of gestation, the author observed an increased farrowing duration only when farrowing induction was conducted on Day 111 (Alexopoulos et al., 1998).

A decreased farrowing duration following induction was also reported (Gokuldas et al., 2015). It is worth noting that the shorter farrowing duration (Gokuldas et al., 2015) came simultaneously with a higher litter size (6.1 vs. 4.8) and higher litter birth weight (9.8 vs. 5.04 kg), and the parity (1−2) was balanced across the control and treatment groups. This result is interesting because it is well established that an increased litter size and litter birth weight will result in an increased farrowing duration (Nam and Sukon, 2020 a). A high dose of cloprostenol (526 µg) might contribute to that interesting result, but it needs to be reevaluated in hyperprolific sows. In a rare experiment that used luprostiol and compared it to dinoprost, Diehl and Newby (1989) reported that three doses, i.e., 3.75, 7.5, and 15 mg of luprostiol, similarly reduced the farrowing duration, while dinoprost failed to produce such results. The difference in potency between the two prostaglandins might result in various effects, and the potential positive effect of luprostiol needs more attention and investigation.

Uterotonic drugs, including oxytocin and carbetocin, have been added to induction programs to increase the predictability of the farrowing time and reduce the farrowing duration. In comparison with oxytocin, carbetocin stimulates less intense but longer uterine contrac-

tions (Ward et al., 2019). The effect of uterotonic drugs on farrowing duration when they are added to induction programs is inconclusive. Most studies have shown that the farrowing duration is not altered when uterotonic drugs are added. Some authors reported numerically shorter farrowing durations, such as 259 vs. 294 minutes (Boonraungrod et al., 2018) or 184–209 vs. 230 minutes (Zaremba et al., 2015). In contrast, in other experiments, the farrowing durations in the uterotonic drug-treated groups were numerically longer than those in the sole $PGF_{2\alpha}$ groups, for example, 194 vs. 183 minutes (Decaluwé et al., 2014) and 175 vs. 150 minutes (Gall and Day, 1987). Notably, in those studies, uterotonic drugs were injected 20–24 h after the injection of prostaglandin when the full opening of the cervix was not confirmed. In a recent study, both oxytocin and carbetocin injection after the birth of the first piglet similarly shortened the farrowing duration in comparison with the program that used cloprostenol alone (Ward et al., 2019). The positive effects of uterotonic drugs on farrowing duration in that study might be due to their injection after the birth of the first piglet when the cervix could be confirmed to be fully opened (Ward et al., 2019). Although this result is interesting, it is questionable whether injection of uterotonic drugs after the birth of the first piglet is the best choice. Mota-Rojas et al. (2007) injected oxytocin after the birth of the 1st, 4th, and 8th piglets and found that although the farrowing duration was not different among groups, the lowest stillbirth rate was found in the last group. A recent study also found that injection of oxytocin after the birth of the 6th–7th piglets produced the most beneficial effects on farrowing durations, birth intervals, and stillbirth (Nam and Sukon, 2022 b). This might be because the sows were low on energy reserves and/or endogenous oxytocin at this point so administration of exogenous oxytocin would enhance the uterine contraction to push the piglets out.

The birth interval is the interval between the births of two successive piglets and has been found to be positively associated with stillbirth (Baxter et al., 2008, 2009; Nam and Sukon, 2020 b). Therefore, it is an outcome that has been considered when farrowing induction is applied. However, recording birth intervals is time- and labor-consuming, and consequently, few studies have included this criterion. Among the available literature, there is only one early study reporting that farrowing induction shortens the birth interval (Diehl and Newby, 1989). In that study, the birth interval in the groups induced with 3.75–15 mg luprostiol ranged from 20.2 to 21.6 minutes, and that in the natural farrowing sows was 32.1 minutes. However, the birth interval in the group induced by 10 mg dinoprost was 35.5 minutes, which was not different from that of the natural farrowing group (Diehl and Newby, 1989). In another study, the birth interval in the cloprostenol split dose group (14.6 minutes) was significantly shorter than that in the single full dose group (20.1 minutes) but did not differ from that in the natural farrowing group (13.3 minutes) (Tospitakkul et al., 2019). In a recent study, the birth interval in the cloprostenol plus either oxytocin or carbetocin groups, although not mentioned by the authors, was probably significantly reduced when compared with that in the cloprostenol alone group (13.9, 11.7, and 18.5 minutes, respectively) (Ward et al., 2019). Recently, using cloprostenol alone, Nam et al. (2022) reported that the birth interval was longer in the induced group than in the control group (21.8 vs. 15.0 minutes). Other studies found that the birth intervals in the control and induced groups were very close to each other (Boonraungrod et al., 2018; De Rensis et al., 2002; Decaluwé et al., 2014; Zaremba et al., 2015). Similar to the case of farrowing duration, the various effects of uterotonic drug addition in induction programs on birth interval might be attributable to the time of application of these drugs.

Birth weight

Birth weight is associated with stillbirth, growth rate, survivability, weight at the slaughterhouse, longevity, and productive performance of pigs (Beaulieu et al., 2010; Feldpausch et al., 2019; Magnabosco et al., 2016, 2015; Nam and Sukon, 2020 b; Paredes et al., 2014). Therefore, a comparison of farrowing induction program outcomes is only effective if the birth weights of piglets are equal or accounted for across treatment groups. Many studies have reported that farrowing induction starting on Days 113–114 does not alter piglet birth weight (Cassar et al., 2005; De Rensis et al., 2002; Decaluwé et al., 2014; Gaggini et al., 2013; Kaeoket, 2006; Otto et al., 2017; Stone et al., 1987; Tospitakkul et al., 2019). In contrast, some other studies have found that farrowing induction reduces piglet birth weight despite the induction program being started on Days 113–114 (Boonraungrod et al., 2018; Gunvaldsen et al., 2007; Mills et al., 2021; Olson et al., 2009; Taechamaeteekul et al., 2022). Premature birthing across species is associated with lighter weights and poor performance. Although Days 113 or 114 are the generally accepted best induction dates, in a herd of naturally longer gestation lengths this could be seen as "premature".

The results of some studies should be interpreted with caution because the difference in the birth weight of piglets may not be attributable to farrowing induction but may be due to the nature of these piglets as seen in the Table 2. Mills et al. (2021) reported that birth weight in the group induced with dinoprost tromethamine plus oxytocin 24 h later was smaller than that in the group induced with dinoprost tromethamine plus 2 doses of oxytocin, 6 hours apart. Similarly, Boonraungrod et al. (2018) found that the birth weight of piglets in the group induced with cloprostenol plus carbetocin was reduced compared with that in the group induced with cloprostenol alone. There is no biologically appropriate link between farrowing induction and reduced birth weight of piglets in such cases (Boonraungrod et al., 2018; Mills et al., 2021). In one study, the birth weight of piglets in the induced group was much heavier than that in the spontaneous farrowing group, i.e., 1.6 vs. 1.05 kg (Gokuldas et

al., 2015). This difference apparently came from the nature of the piglets rather than the effect of any treatments applied one day (Day 114) before farrowing.

On the other hand, birth weight is positively associated with gestation length and negatively associated with litter size. Therefore, when examining the effect of farrowing induction on the birth weight of piglets, one should consider those factors in study design and analysis. In the study by Gunvaldsen et al. (2007), the decreased birth weight in the induced groups might be attributable to both a shorter gestation length (115.1, 115.1 vs. 117.0 days) and a larger litter size (12.04, 11.92 vs. 11.08). Similarly, in the study by Olson et al. (2009), the reduced birth weight in the cloprostenol group might be due to a 2.1-day shorter gestation length in this group in comparison with that in the control group. In these two studies, the induction, although conducted on Days 113−114, started approximately 3 days before the expected farrowing date (Gunvaldsen et al., 2007; Olson et al., 2009). Therefore, the available literature suggests that if farrowing is induced 1−2 days before the expected farrowing, it would not alter the birth weight of the piglets. Because the gestation length of sows in different farms may vary, farrowing induction should be conducted based on the history of sows' gestation length on each farm.

Dystocia and birth assistance

Evaluation of the effects of farrowing induction on dystocia and birth assistance is challenging because the definition of dystocia is inconsistent among studies. Alexopoulos et al. (1998) defined a dystocia event as when the birth interval exceeded 20−30 minutes, while Mills et al. (2021) and Tospitakkul et al. (2019) used a birth interval of 30 minutes as the cutoff value to define dystocia/birth assistance. Other studies used a cutoff of 45 minutes (Decaluwé et al., 2014; Nam et al., 2022; Tospitakkul et al., 2019; Zaremba et al., 2015). Boonraungrod et al. (2018) even used a looser cutoff of 30−60 minutes. An accurate prediction of dystocia and birth assistance requires an accurate recording of birth intervals. However, this is a laborious process and it may vary among farrowing supervision protocols. Therefore, monitoring devices that are capable of continuously recording a video of sows during their farrowing may assist with this.

A few studies have assessed the effect of farrowing induction on birth assistance and dystocia. Mills et al. (2021) reported that the dystocia rates in sows in two induced groups with dinoprost tromethamine alone and plus oxytocin and a control group were very similar (13.8, 14.9, and 13.3%). Another study also found no effect of farrowing induction on the rate of dystocia (53.6, 26.7, and 41.7%) among the single full dose of cloprostenol, split dose of cloprostenol, and control groups (Tospitakkul et al., 2019), despite an increase in farrowing duration and birth interval in the single full dose group. In contrast, in a recent study, Boonraungrod et al. (2018) found that the percentage of sows needing birth assistance was significantly higher in the cloprostenol plus carbetocin group than in the cloprostenol alone and control groups (73.6, 50, and 33.8%), although no difference in farrowing duration and birth interval was detected. Zaremba et al. (2015) reported that different induction programs resulted in various rates of dystocia at the farrowing level. In that study, the dystocia rate at the farrowing level was 21.0, 19.8, 11.4, and 13.8% when sows were induced with cloprostenol alone, cloprostenol plus 20 IU oxytocin, cloprostenol plus 70 µg carbetocin, and cloprostenol plus 35 µg carbetocin, respectively. At the piglet level, Decaluwé et al. (2014) substantiated that the number of dystocia events per litter ranged between 0 and 1 without any significant difference. In contrast, a split dose of cloprostenol reduced the rate of piglets needing birth assistance compared with a single full dose and control (2.7 vs. 11.8 and 10.6%) (Tospitakkul et al., 2019). Recently, it was demonstrated that farrowing induction with 175 µg cloprostenol on Day 114 increased the dystocia rate at both sow (90 vs. 50%) and piglet (11.5 vs. 6.3%) levels (Nam et al., 2022).

Table 2. Some potential confounding factors that might influence the effect of farrowing induction on certain farrowing characteristics

Outcomes/Authors	Potential confounding factors
Decreased birth weight in the group induced with dinoprost tromethamine plus oxytocin 24 h later as compared with that in the group induced with dinoprost tromethamine plus oxytocin at 6 and 12 h later (Mills et al., 2022)	There was a natural difference in birth weight between the 2 groups
Decreased birth weight in the group induced with cloprostenol plus carbetocin 24 h later as compared with that in the group induced with cloprostenol (Boonraungrod et al., 2018)	There was a natural difference in birth weight between the 2 groups
Decreased birth weight in the control group (Gokuldas et al., 2015)	There was a natural difference in birth weight between the 2 groups
Decreased stillbirth in the induced group (Nguyen et al., 2011)	Sows in the induced group were supervised, whereas those in the control group were not supervised
Decreased stillbirth in the induced group (Gokuldas et al., 2015)	There was a higher birth weight in the induced group than in the control group
Increased stillbirth in the induced groups (Taechamaeteekul et al., 2022)	There was a possible effect of altrenogest treatment

Stillbirth

Stillbirth is the most important outcome to be evaluated when farrowing induction is applied because it relates to economic benefit, sow reproductive performance and animal welfare issues. Almost all available studies found that farrowing induction did not influence the stillbirth rate (Boonraungrod et al., 2018; Cassar et al., 2005; Decaluwé et al., 2014; Fraser and Connor, 1984; Gaggini et al., 2013; Gunvaldsen et al., 2007; Kirkwood and Aherne, 1998; Mills et al., 2021; Nam et al., 2022; Olson et al., 2009; Otto et al., 2017; Smith et al., 2013; Vallet and Miles, 2017). The similarity among the abovementioned studies was that their induction programs did not start on Days 113−114, and the largest difference in gestation length among treatment groups and control groups was approximately 1 day. Some studies reported an increased stillbirth rate with farrowing induction (Alexopoulos et al., 1998; Yang et al., 1996) when the induction was conducted on Day 111. The difference in gestation length between the control and treatment groups seems to be more important than the day of induction because different sow populations may have various natural gestation lengths. In the study by Alexopoulos et al. (1998), farrowing was induced on either Days 111, 112, or 113, the respective gestation length was 2.4−2.6 days, 1.5−1.7 days, and 0.8−0.9 days shorter in the induced groups, and only induction on Day 111 increased the number of stillbirths per litter. Similarly, the reduction of 2.5−2.7 days in gestation length in the treatment group resulted in an increased stillbirth rate (Yang et al., 1996). However, the induction on Days 111−113 with a 1.0−1.2 day reduction in gestation length did not increase the number of stillbirths per litter (Gall and Day, 1987).

By contrast, some authors showed that farrowing induction reduced the stillbirth rate (Cerne and Jöchle, 1981; Gokuldas et al., 2015; Leethongdee et at., 2012; Nguyen et al., 2011). In the study by Nguyen et al. (2011), only induced sows were supervised, and this might have influenced the findings because supervision influenced the stillbirth rate (Le Cozler et al., 2002). In the work by Gokuldas et al. (2015), the stillbirth rate in the induced group was approximately 3 times lower than that in the control group (8.0 vs. 24.4%). However, these results should be interpreted with caution because there was a difference in the nature of the investigated animals. The average birth weight of the piglets in the induced group was 1.6 kg and that of piglets in the control group was only 1.05 kg. Piglets smaller than 1.11 kg were defined as runt piglets (Feldpausch et al., 2019; Magnabosco et al., 2015). Therefore, many of these control piglets might have acquired intrauterine growth retardation and subsequently been more prone to stillbirth. In the work by Leethongdee et al. (2012), the number of stillbirths per litter was lower in the induced group, and the litter size, which was positively associated with stillbirth, was smaller (11.8 vs. 13.35). Therefore, the beneficial effect of farrowing induction on stillbirth rates should be interpreted with caution and in consideration of other factors, such as supervision, birth weight, and litter size.

The use of other drugs before induction might also intervene with the stillbirth rate (Table 2). Recently, Taechamaeteekul et al. (2022) used cloprostenol to induce altrenogest-treated sows on Days 113, 114, and 115 and found that the stillbirth rate ranged from 11.8 to 17.2% in the induced groups and was 5.8% in the control group. In that study, the rate of mummified fetuses, although not significantly different, was numerically higher in all the treated groups than in the control group (3.2−3.8 vs. 1.3%). This implied that the number of prepartum deaths, which was unlikely to be caused by farrowing induction, had already been higher in the treated groups than in the control group before the induction program was initiated. Additionally, fetuses alive until the beginning of the induction program might have been affected by altrenogest supplementation and then were at a higher risk of stillbirth during parturition. This suggested that the higher stillbirth rate in the treated groups might have been due to altrenogest supplementation (Taechamaeteekul et al., 2022) or some unknown reasons rather than farrowing induction.

Conclusion

The current overview shows that different farrowing induction programs produce various effects on birthing characteristics in the pig. Among them, a split dose of prostaglandins is believed to induce complete luteolysis and decreases the farrowing duration, birth interval, and dystocia in comparison with a single full dose. Additionally, the use of uterotonic drugs after the birth of at least one piglet when the cervix has fully opened rather than 24 h after the prostaglandin injection can shorten the farrowing duration. When evaluating the effects of farrowing induction on certain farrowing characteristics, one should consider potentially confounding factors such as the rate of farrowing supervision, the natural difference in birth weight of piglets, the litter size, the difference in gestation length between induced and control groups, and the effect of other treatments applied before farrowing induction. To minimize a potentially negative effect of farrowing induction on birth weight and stillbirth, the induction program should be started 1−2 days before the expected farrowing date of sows in each specific farm. Because induction is a labor intense management strategy and with the current global labor shortage situations or drive for efficiency there needs to be further refinements or researches in this area to ensure the benefits of the induction programs over their costs.

Author's contribution

Conceptualization (NHN, PS), reference retrieval (NHN, LTLT, NTL, NVN), data extraction (NHN, LTLT, NTL, NVN), manuscript preparation (NHN, PS, DTKL, BTAD, NDT, TMH) and approval (NHN, LTLT, NTL, NVN, BTAD, TMH, NDT, DTKL, PS).

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Conflict of interest

The authors declare that they have no conflicts of interest.

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