Research Article

Meta-Analysis: Reproductive Parameters of Crossbred *Bos taurus* and *Bos indicus* in Tropical Environments

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Abstract | Crossing *Bos indicus* and *Bos taurus* was expected to produce more productive and adaptable progeny, but contrary to expectations, their crossbreds are prone to several reproductive disorders, and poorer reproductive qualities. The research about the reproductive quality between two species showed different result. The aim of this research is to compared the reproductive quality of *Bos indicus* crossbred and their crossbreds with *Bos taurus*. A meta-analysis involving 43 studies on reproductive hormone levels, 25 studies on estrus activity and 65 studies on reproductive performance. Article search, article selection, data extraction, statistical analysis (heterogeneity, summary effect, publication bias test) were used in this meta-analysis. Statistical analysis was supported by Open MEE and R Studio. The results show that *Bos indicus* have lower progesterone levels in the proestrus phase compared to their crossbred with *Bos taurus*, but no significant difference in other reproductive hormone levels. This also occurs in estrus activity parameters, where there is no significant difference in the estrus cycle and duration between *Bos indicus* cattle and their crossbred with *Bos taurus*. No significant differences in several reproductive parameters due to adaptation or resistance to stress. The increase in progesterone levels during proestrus phase on crossbred cattle is the reason for the occurrence of delayed ovulation, thus requiring external hormone intervention. Based on the finding, *Bos indicus* crossbred cattle are more recommended to be raised in tropical areas with high environmental temperature. Further meta-analysis that categorized the reproductive quality of crossbred cattle based on the location altitude, feeding management, age and/or parity, needs to be conducted to determine the most optimal rearing conditions.

Keywords | Crossbred cattle, Meta-analysis, Reproductive parameters

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INTRODUCTION

The crossbred of *Bos indicus* cattle are raised extensively in Indonesia because they have adapted to tropical climates. Particularly in lowland areas with relatively high temperatures, these cattle can adapt well to Indonesia tropical climate. One example of crossbred of *Bos indicus* is the Ongole crossbred. Ongole crossbred can adapt well to variety of environmental disturbances, including high temperatures and parasitic insects like ticks and mosquitoes that are frequently found in tropical regions (Susilawati, 2017). Nonetheless, given their smaller stature in comparison to *Bos taurus* cattle, these animals might be less productive. Therefore, it is expected that crossing them with *Bos taurus* cattle will produce more productive and adaptable progeny. In such case, local farmer in Indonesia have crossbred Ongole cattle with Limousine and Simmental cattle using artificial insemination. This practice

has led to the creation of new crossbred cattle, specifically Simmental-Ongole crossbred (SimPO) and Limousine-Ongole crossbred (LimPO) cattle. Similarly, farmers in other tropical regions also undertake crossbreeding between these two species, such as crossing Brahman and Angus cattle to produce Brangus, or crossing Nelore cattle with Angus. However, many reproductive disturbances are encountered in crossbred cattle. This is suspected to be a consequence of the crossbreeding of these two species.

Contrary to expectations, crossbred cattle have been found to have poorer reproductive qualities. SimPO and LimPO crossbreds are prone to several reproductive disorders, including silent heat, prolonged estrus, delayed ovulation, and repeated breeding. Research by Arun *et al.* (2020) in Kerala, India showed that 25.86% of crossbred cattle exhibiting prolonged estrus, 25.96% crossbred cattle were repeat breeder and among the repeat breeder cattle, 55,42% of them also exhibited prolonged estrus. According to Aryogi and Adinata (2015), SimPO and LimPO cattle have service per conception (S/C) value of 2.02 ± 0.69, and 1.97 ± 0.72, both higher than PO cattle, which have S/C value of 1.56 ± 0.75. Artificially inseminated (AI) SimPO and LimPO cattle typically have high S/C values, which are deemed ineffective and detrimental to breeders.

Reproductive disorder suspected to occur because crossbred cattle's limited ability to adapt to tropical climates results in heat stress and lower reproductive quality. Heat stress causes the body to produce more stress hormones, like cortisol, which speeds up the breakdown of protein and triglyceride fats into gluconeogenesis and has a deleterious effect on livestock reproduction. Cattle's reproductive processes may be impacted by high concentrations of non-esterified fatty acids (NEFA), which are produced by the process of gluconeogenesis from fats. Cattle with high NEFA content in follicular fluid have a decrease in the morphological quality of cumulus-oocyte complexes, which prevents the maturation of oocytes and the division of embryo cells, according to Baddela *et al.* (2020).

Cortisol-stimulated gluconeogenesis during stress reduces the portion of protein available for the of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) formation. These hormones are glycoprotein hormones that play a crucial role in growth and maturation of follicles and ovulation, significantly influencing cattle fertility. The follicular phase, which begin with corpus luteum regression and ends with onset of estrus, involves a rapid decrease in progesterone that causes an increased in LH and a subsequent rise in follicular estradiol secretion (Pohler, 2020). The disruption of these reproductive hormone production will disrupt the reproduction condition of the cattle. Cortisol also triggers the secretion of gonadotropin inhibitory hormone (GnIH), which inhibits the secretion of gonadotropin hormones. According to Smith and Clark (2010), GnIH has a negative effect on the mammalian reproductive system due to its inhibitory nature on gonadotropin hormone production.

Reproductive disorders in general lead to a decline in the success of mating in livestock. PO cattle have superior reproductive performance than SimPO cattle, according to a study conducted in lowland areas of Trenggalek and Ponorogo regencies by Yulyanto *et al.* (2014). Conversely, SimPO and LimPO cattle appear to perform better reproductively than PO cattle, according to research by Kuswati *et al.* (2015). Several other studies also yielded different results. *Bos indicus* cattle are confirmed to have superior reproductive quality by Akriyono *et al.* (2017), Widiati *et al.* (2019), and Priyo-Jr *et al.* (2020). On the other hand, studies by Kuswati *et al.* (2015) and Christoffor and Baliarti (2008) revealed the opposite. However, research by Fauziah *et al.* (2015), Erni (2023), Dwitarizki *et al.* (2017), Riyanto *et al.* (2015), Nasuha *et al.* (2019), and others found no differences in the reproductive quality of *Bos indicus* and their crossbreds with *Bos taurus*. The inconsistency occurs because the research conducted in various region and condition. Moderator variables such as different rearing areas, environmental conditions, and the cattle conditions such as age and BCS could influence the research outcome. Therefore, meta-analysis was conducted to eliminate the influence of the existing moderator variables.

Based on above consideration, we hypothesize that there will be significant differences in reproductive parameter between *Bos indicus* crossbred and their crossbreds with *Bos taurus*. Specifically, we predicted that *Bos indicus* crossbred will exhibit shorter estrus duration, and better reproductive performance compared to their crossbred with *Bos taurus*. In order to compare and answer the question of whether there are differences in reproductive parameters between *Bos indicus* crossbred and their crossbreds with *Bos taurus*, this meta-analysis was carried out in response to the disparate findings of these studies.

The meta-analysis combines research results on estrus activity, reproductive hormone levels, and reproductive performance of *B. taurus* cattle and their crossbreds with *B. taurus* cattle, making statistical computations easier and producing more accurate results. The aim of this research is to compared the reproductive hormone levels, estrus activity, and reproductive performance between *Bos taurus* crossbred and *Bos indicus* crossbreed cattle raised in tropical regions based on a meta-analysis study.

MATERIALS AND METHODS

This research using a meta-analysis method by utilizing scientific publications, including journals and proceedings,

that contain reproductive parameters of crossbred *Bos indicus* and *Bos taurus* cattle in tropical environment. This meta-analysis research was done from June until September 2023.

Rationale for choosing meta-analysis

Based on the introduction, there was a need to standardize the perception of the reproductive parameters between the two species. This could be achieved through experimental research that conducted under standardized environmental setting. However, the diverse condition of the tropical climate across regions and countries making it difficult to control the environment that can represent the entire tropical area. Meta-analysis can provide conclusions that eliminates the influence of moderator variables without requiring environmental setting, thus offering a cost-effective solution. Therefore, meta-analysis was considered the most suitable approach to take.

Article selection

Database search using keywords related to reproduction, such as progesterone, estrogen, follicle-stimulating hormone (FSH), luteinizing hormone (LH), estrus cycle, estrus duration, service per conception (S/C), post-partum estrus (PPE), calving interval (CI), beef cattle, and crossbred cattle yielded a total 367 articles that match the keyword.

The articles were then selected according to the inclusion criteria. Inclusion criteria were met when the articles consisted of Indonesian or English, published from 2004 to 2023, containing data of the mean and standard deviation (SD), includes moderator data such as age, body condition score (BCS), location, and the research being conducted in the tropical areas. Articles that failing to meet these criteria were excluded from further consideration.

Data processing was carried out using Microsoft Excel to compile information from the selected studies. This step tabulated the data of authors, publication year, mean, SD, sample size (n) and the moderator data. The data on estrus behavior parameters were extracted from 8 articles, producing 25 studies on estrus cycles and duration. Hormone level parameters were extracted from 10 articles, producing 43 studies on progesterone, estrogen, FSH, and LH hormone levels. Reproductive performance parameters were extracted from 13 articles, producing 28 studies on service per conception (S/C), 14 studies on post-partum estrus (PPE), and 23 studies on calving interval (CI).

The article selection process was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method using Review Manager 5.4.1, as depicted in Figure 1.

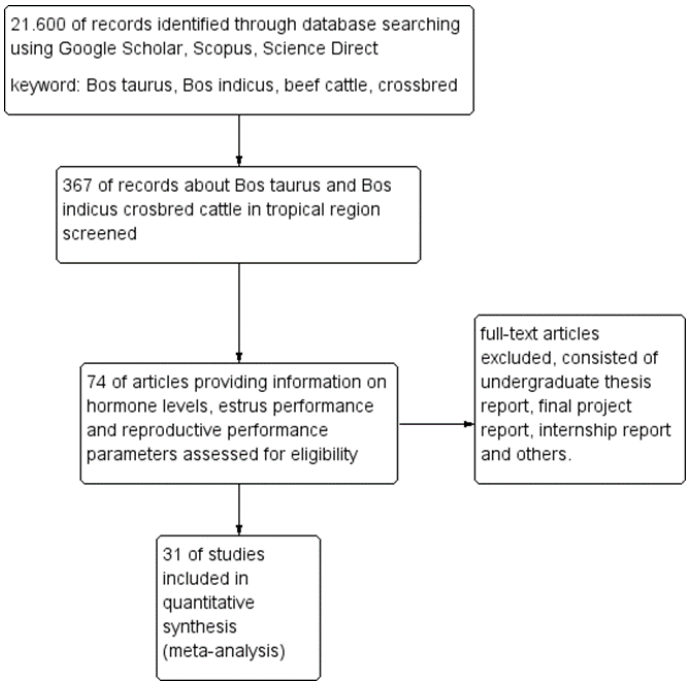

Figure 1: Flow of article selection.

Statistical analysis

The interpretation of data from the collected articles was conducted using R Studio and Open Meta-analyst for Ecology and Evolution (OpenMEE). The reproductive hormone and estrus activity parameters were processed using a linier mixed model (LMM) through R studio, because the data collected were more suitable for LMM analysis. There were not enough finding that compare reproductive hormone or estrus activity between the two species in a single article.

Reproductive hormone parameters include studies on progesterone, estrogen, FSH, and LH hormones during the estrus phase. Reproductive performance parameters consisted of the values for service per conception (S/C), post-partum estrus duration (PPE), calving interval (CI), estrus duration, and estrus cycle length.

Analysis using LMM with R studio 4.3.1 version, using 'lme()' effect to specify the mixed effect model and 'summary' effect to get the overall effect size estimated or the summary effect. The analysis using species as the fixed effect and the studies as random effect. The mathematics model following basic linear mixed model equation that written as:

$$Y_{ij} = \beta_0 + \beta_1 Spesies + Study_i + e_{ij}$$

While the reproductive performance parameters were processed using the OpenMEE application, because each study compared and categorized variables based on 2 species of cattle. The reproductive performance studies include data on cattle species as the treatment experiment, with

Bos indicus crossbred cattle as the control and it's crossbred with *Bos taurus* cattle as the experimental treatment.

Meta-analysis conducted using OpenMEE application, including computing heterogeneity, summary effect, and publication bias test. Heterogeneity was measured using the I^2 formula, which serves as an indicator of the proportion of variation attributed to genuine effects when sampling error is eliminated. The I^2 value ranges from 0 to 100%, representing the degree of variation in study data. Higgins *et al*. (2003) state that the higher the I^2 value, the higher the heterogeneity.

The final stage of meta-analysis involves measuring the effect size to determine the summary effect that determine the relationship between crossbreeding in beef cattle and the parameters of hormone levels, estrus behavior, and reproductive performance. The measurement of effect size between study group contrasts was carried out by comparing the results of variance analysis between the experimental and control groups. Cohen (1988) states that there are three categories in measuring the summary effect: Strong if the value is ≥ 0.5, moderate if the value is 0.5-0.3, and weak if the value is 0.3–0.1.

Evaluation

The presence of bias affects the quality of meta-analysis results, leading to low validity. It can be detected through, funnel plot and fail-safe N. fail-safe N is conducted to further confirm the presence of publication bias, which may be challenging to discern through a funnel plot alone. Fail-Safe N test produce NR value, suggested that if $NR > 5k + 10$ where k is the number of studies, the likelihood of publication bias would be minimal.

RESULTS AND DISCUSSION

Hormone level

Data for hormone level parameters including 13 articles, resulting in 21 studies on progesterone, 8 studies on estrogen, 6 studies on FSH, and 8 studies on LH. The results of the meta-analysis calculations are presented in Table 1. The results of the meta-analysis indicate that the progesterone levels in crossbred cattle during proestrus phase are higher but there is no difference in the other hormone levels between *Bos indicus* crossbred and their crossbreds with *Bos taurus*.

Progesterone

The progesterone levels in *Bos taurus* crossbred during the proestrus phase are higher than those in *Bos indicus* crossbred. The progesterone profile during the proestrus phase should decrease to trigger an increase in LH for the ovulation process and transition to the estrus phase. Aryogi and Adinata's (2015) have similar results, that the progesterone hormone in crossbred *Bos indicus* and *Bos taurus* cattle raised in lowland areas is higher during the proestrus phase. This supports the theory that the decline in reproductive performance in crossbred cattle is due to disruptions in reproductive hormones influenced by environmental conditions that do not align with the physiological needs of the livestock. Satheshkumar *et al*. (2015) research on crossbred cattle demonstrated the impact of high temperatures on follicle growth and function, leading to summer infertility syndrome in crossbred cattle. In this study, crossbred cattle exhibited higher progesterone levels during the estrus phase in the summer. These crossbred cattle are more susceptible to heat stress due to their genetic characteristics, as evidenced Goud *et al*. (2019) research comparing *B. taurus, B. indicus*, and their crossbreds, indicated that cattle with lower Melanocortin-1 receptor (MC1R) gene regulation ability have brighter body color and higher heat regulation capabilities.

Table 1: Results of meta-analysis for hormone level parameters.

Parameter	n	Parameter estimates		Model estimates		
		Intercept	SE intercept	Slope	SE slope	p value
Progesterone	21	1.93	0.69	1.45	0.53	0.02
Estrogen	8	34.75	6.63	-0.46	8.38	0.96
FSH	6	2.09	3.15	1.09	2.95	0.75
LH	8	0.32	0.02	0.01	0.04	0.75

Estrogen

The results of the meta-analysis indicate that there is no difference in estrogen hormone levels between *Bos indicus* crossbred and their crossbreds with *Bos taurus*. The studies show different results, Aryogi *et al*. (2020) study reveals an interaction between breed and the altitude of the livestock location regarding estrogen hormone levels before estrus. Alfons *et al*. (2022) research on *Bos indicus* and *Bos taurus* crossbred cattle raised in Sleman regency shows no difference in estrogen hormone levels approaching estrus between the two types of cattle. The absence of differences in various reproductive hormone conditions is attributed to the adaptation or resistance of livestock to stress.

Chronic stress occurring continuously over a long period can lead to the development of reproductive system resistance to stress. Gantner *et al*. (2017) study indicates that multiparous cows have higher resistance to heat stress compared to primiparous cows. According to Chen *et al*. (2015), prolonged stress can cause changes in behavior, endocrine, immune, and metabolic systems, leading to adaptations involving both increased and decreased body responses to stress. This includes changes in the

reproductive system's response to stress. Resistance to stress occurs for several reasons, such as the central nervous system no longer perceiving stress as a threat, inhibition of the HPA axis resulting in decreased glucocorticoid production, a decrease in reproductive organ sensitivity to glucocorticoid hormones, and mechanisms to neutralize the negative effects of stress hormones.

Follicle stimulating hormone (FSH)

The results of the meta-analysis indicate that there is no significant difference in FSH levels between *Bos indicus* crossbred and their crossbreds with *Bos taurus*. The production of FSH is regulated by GnRH produced by the hypothalamus. Stress conditions lead to the inhibition of GnRH secretion, causing the suppression of gonadotropin hormones, including FSH and LH. Niyas *et al.* (2015) state that environmental stress affects livestock, enabling adaptation at physiological, morphological, and endocrine levels, but the productive potential of the livestock must be sacrificed. This can be seen in the lower reproductive performance values of *Bos taurus* crossbred compared to *Bos indicus* crossbred.

Luteinizing hormone (LH)

The results of the meta-analysis indicate that there is no difference in LH hormone levels during the proestrus phase between *Bos indicus* crossbred and their crossbreds with *Bos taurus*. The studies used collectively conclude that there is no significant difference between the two species. The first study by Yuwono *et al.* (2017) on PO cattle and SimPO cattle, both single and twin births, did not show significantly different LH hormone levels. The second study by Junior *et al.* (2012) on Nelore cattle raised in four different seasons did not demonstrate any differences in LH levels during the proestrus phase, despite having significantly different progesterone levels during the diestrus phase.

Estrus activity

Data for the estrus activity parameter consist of 17 articles, resulting in 8 studies on estrus duration and 17 studies on estrus cycle. The results of the meta-analysis are presented in Table 2. The results of the meta-analysis indicate that there is no difference in the estrus duration and estrus cycles of *Bos indicus* crossbred and their crossbreds with *Bos taurus*.

Estrus duration

The results of the meta-analysis from the accumulated studies on the duration of estrus in *Bos indicus* crossbred and their crossbreds with *Bos taurus* indicate that there is no significant difference in the duration of estrus between the two types of cattle. The duration of estrus is primarily influenced by estrogen hormone levels.

Kurniadi (2022) study on SimPO cattle experiencing prolonged estrus shows a longer estrus duration with an average of 78±12 hours, attributed to high progesterone and low estrogen levels in the blood during the estrus phase. Febrianti *et al.* (2022) research involving the administration of vitamin E demonstrates a normal estrus duration in SimPO cattle. This occurs because vitamin E can eliminate the influence of stress, allowing folliculogenesis and estrogen production processes to proceed smoothly, leading to normal cattle estrus.

Data on the estrus duration parameter from studies conducted across different conditions show no significant influence from *Bos indicus* crossbred and *Bos taurus* crossbred. This implies that both species do not experience stress that can alter the duration of estrus.

Estrus cycle

The results of the meta-analysis from the accumulated studies on the duration of estrus cycles in *Bos indicus* crossbred and their crossbreds with *Bos taurus* show that there is no significant difference in the estrus cycle between the two species. Research by Tiro *et al.* (2020) indicates no significant difference in the estrus cycle of PO and SimPO cattle, even though they have different progesterone profile. Kurniadi's Research (2022) explains a specific condition where SimPO cattle experiencing prolonged estrus show a longer estrus cycle ranging from 22 to 23 days, with an average value of 22.5±0.57 days. This occurs due to an increase in progesterone caused by incomplete luteolysis of the corpus luteum (CL) and environmental stress stimulation, hindering the follicular process.

Data on the estrus cycle parameter from the obtained studies indicate no significant difference between *Bos indicus* crossbred and *Bos taurus* crossbred. This aligns with the results of the estrus duration parameter that shows no significant difference. Data from different environments and management indicate that cattle do not experience

Table 2: Result of meta-analysis estrus activity parameter.

Parameter	n	Parameter estimates		Model estimates			
		Intercept	SE intercept	Slope	SE slope	p value	R2
Estrus duration	8	50.5	19.54	-37.48	27.61	0.31	-
Estrus cycle	17	22.29	1.46	-2.00	2.12	0.38	0.053

Table 3: Result of meta-analysis reproductive performance parameter.

Studies	Crossbred	B. indicus	Het. P value	Estimate	p value	Fail-safe N value	Fail-safe N limit
S/C	1.95±0.53	1.75±0.45	0.198	0.238	<0.001	209	150
PPE (days)	113.75 ± 22.50	126.66 ± 24.83	0.016	−0.401	<0.001	122	80
CI (days)	473.21 ± 67.29	458.40 ± 44.20	<0.001	0.426	0.026	202	125

stress that can affect the occurrence of estrus cycles. This may be due to stress occurring briefly or at specific times, for example, heat stress only occurring during the daytime. Maziero *et al.* (2011) research shows that acute stress events, even though they can affect cortisol and progesterone levels, do not influence the duration of estrus in cattle.

Reproductive performance

Reproductive performance data consist of 13 articles, resulting 28 studies on service per conception (S/C), 14 studies on post-partum estrus (PPE), and 23 studies on calving interval (CI). The results of the meta-analysis are presented in Table 3. The results of the meta-analysis indicate that the crossbred cattle reach PPE quicker but have higher S/C and longer CI. The heterogeneity test result showed that the S/C have heterogenies studies, then the PPE and CI parameters showed homogeny studies. The Rosenthal's Fail-safe N result showed that there is no publication bias on the reproductive performance parameters. Based on Borenstein *et al.* (2009), this mean that the meta-analysis results are robust and the pattern of the result is not affected by the bias.

Service per conception (S/C)

The collected studies on the S/C of *Bos indicus* crossbred and *Bos taurus* crossbred results are presented in Table 3. The p-value from the forest plot indicates the influence of crossbreeding on the Service per Conception (S/C) value in beef cattle. The total estimated value indicates that crossbreeding has a positive effect of 23.8% on the S/C value of cattle. PO cattle have lower S/C values because of their better reproductive quality when raised in tropical areas. Moura *et al.* (2021) demonstrated that crossbred *B. indicus* and *B. taurus* cattle have higher heat production than purebred cattle, making them more susceptible to heat stress. Silva *et al.* (2013) found that in heat stress conditions, *B. taurus* cattle embryos have better resilience than *B. taurus* cattle, resulting in higher conception success.

Reproductive disorders in cattle can affect the success of mating, thereby increasing the S/C value. Salman *et al.* (2021) studied beef cattle in Jepara Regency experiencing reproductive disorders, resulting in a high S/C value of up to 4.15. Sutiyono *et al.* (2017) mentioned that one reproductive disorder in smallholder farms is ovarian hypofunction, leading to the low ability of animals to produce high-quality ovum, thus reducing fertilization success.

The farm location also influences the S/C value. Widiati *et al.* (2019) conducted a study in Gunung Kidul Regency, showing S/C results for LimPO cattle at 1.83 ± 0.79 and PO cattle at 1.90 ± 0.80, while in Bantul, LimPO cattle had S/C values of 2.23 ± 0.97 and PO cattle had 2.50 ± 1.59. This study noted that Gunung Kidul Regency has more green fodder available, and the use of pollard as livestock feed, which has higher phosphorus and potassium content compared to rice bran. Pranata *et al.* (2016) mentioned that feed with higher protein content improves the quality of ova and embryos in Simental cattle.

Post partum estrus (PPE)

The collected studies of postpartum estrus (PPE) in *Bos indicus* crossbred and *Bos taurus* crossbred results are presented in Table 3. The p-value from the forest plot indicates the influence of crossbreeding on the postpartum estrus (PPE) value in beef cattle. The total estimated value shows that crossbreeding has a negative impact of 40.1% on the S/C value in cattle. This outcome suggests that crossbred cattle have a shorter PPE duration compared to PO cattle.

The stress experienced by cattle affects the duration of PPE. Fernandez-Novo *et al.* (2020) state that there is an increase in prolactin hormone in cattle experiencing stress due to the active hypothalamus-pituitary-adrenocortical (HPA) axis. The acceleration of PPE due to prolactin hormone causes cattle experiencing heat stress to reach PPE faster, even though the reproductive organ's performance is not perfectly healed. This can be observed from the longer calving interval (CI) values, even though crossbred cattle have a shorter PPE. Ogino *et al.* (2014) study indicates that cattle management during the summer shows an increase in prolactin levels, while a decrease occurs during the winter season.

A shorter PPE duration does not necessarily indicate better reproductive performance in livestock. This is because a shorter PPE duration does not guarantee good estrus quality. Cheong *et al.* (2016) study demonstrates that, despite experiencing estrus simultaneously, cattle under stress induced negative energy balance (NEB) have lower concentrations of estrogen hormone, resulting in ovulation failure.

Calving interval (CI)

The collected studies of calving interval (CI) in *Bos indicus*

crossbred and *Bos taurus* crossbred results are presented in Table 3. The p-value from the forest plot indicates the influence of crossbreeding on the calving interval (CI) value in beef cattle. The total estimated value shows that crossbreeding in beef cattle has a positive impact on the CI duration. This means that the study data indicates that crossbred cattle have a longer CI duration compared to *Bos indicus* crossbred.

Bos indicus cattle develop mechanisms to cope with fluctuating nutrient availability through insulin regulation. Sartori *et al.* (2016) study indicates that *Bos indicus* cattle have higher circulation of insulin and insulin-like growth factor (IGF-1) compared to *Bos taurus*, even with the same dry matter intake (DMI). This supports the idea that PO cattle have better reproductive quality than SimPO and LimPO, even when fed low-quality forage.

However, different results were observed in 8 out of 23 studies used. Widi *et al.* (2015), in high-altitude farm, showed lower CI values in crossbred cattle compared to PO cattle. This is because the high-altitude environment is more suitable for the life of crossbred cattle. San *et al.* (2015) research indicates that SimPO cattle raised at high altitudes (700-2579 masl) have better reproductive performance compared to those raised at low altitudes (30-700 masl).

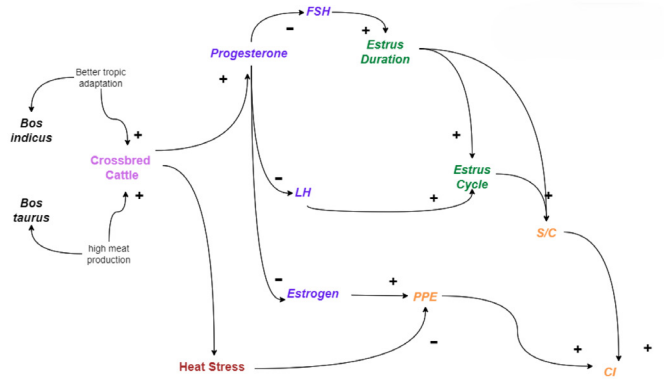

Figure 2: Causal loop of reproductive parameters of *Bos indicus* and *Bos taurus* crossbred.

General discussion

The correlation between reproductive parameters of *Bos taurus* and *Bos indicus* crossbred cattle can be seen in Figure 2. The *Bos taurus* and *Bos indicus* crossbred cattle had an increase in progesterone levels during the proestrus phase. Progesterone levels that remain high will inhibit the production of FSH and estrogen hormones, that inhibits follicular growth. Research by Abreu *et al.* (2018) states that cattle with lower progesterone levels during the early days of follicle formation have faster follicle growth, resulting in higher estrogen concentrations, and better stimulation of the LH hormone. The inhibition of follicle formation certainly slows down the ovum maturation, that makes ovulation does not occur according to the normal estimated time.

The increase in progesterone during the proestrus phase was not followed by a decrease in the levels of estrogen, FSH and LH. This is the reason for the absent difference in the duration and length of the estrous cycle between the two species. The absence of differences in reproductive hormone levels occurs because the cattle have undergone adaptation to be more resistant to stress. This was in accordance with Chen *et al.* (2015) that there is a change in response to the reproductive system due to prolonged stress.

The test results showed differences in reproductive performance between the two species, although there were no differences in the estrus activity and some reproductive hormones. This was showed by higher S/C and CI values in crossbred cows, although this species reached PPE sooner. PPE in crossbred *Bos indicus* and *Bos taurus* cows is achieved faster due to the effect of heat stress on accelerating prolactin hormone production. This is consistent with the research by Ogino *et al.* (2014) that cattle reared in summer experience increased prolactin production, when compared to winter rearing.

CONCLUSIONS AND RECOMMENDATIONS

The meta-analysis result indicates a variation in progesterone levels during the proestrus phase and reproductive performance parameter between *Bos indicus* crossbred and their crossbred with *Bos taurus*, however there was no difference in estrogen, FSH, LH levels, as well as estrus activity parameter between the two species. The increase in progesterone levels during proestrus phase on crossbred cattle is the reason for the occurrence of delayed ovulation, thus requiring external hormone intervention.

Based on the finding, *Bos indicus* crossbred cattle are more recommended to be raised in tropical areas with high environmental temperature. Further meta-analysis that categorized the reproductive quality of crossbred cattle based on the location altitude, feeding management, age and/or parity, needs to be conducted to determine the most optimal rearing conditions.

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NOVELTY STATEMENT

To the best of our knowledge, this is the first meta-analysis study about reproductive parameter of Bos taurus and Bos indicus crossbred cattle.

AUTHOR'S CONTRIBUTION

The whole author of this article was contributing to analyze the data and writing the article

Conflict of interest

The authors have declared no conflict of interest.

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