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RELATIONSHIP BETWEEN BODY CONDITION SCORE AND FERTILITY OUTCOMES IN GRAZING BUFFALOES

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Abstract: The objective of this study is to determine the body condition score (BCS)-reproductive outcome in grazing buffaloes in semi-intensive field conditions. A standardized 5-point BCS system was utilized to record 200 multiparous Murrah and Nili-Ravi buffaloes at prepartum, postpartum, and first artificial insemination (AI) phases. A complete reproductive record and analysis were made, including days to first estrus, days open, services/conception and conception rates along with metabolic profiles and diet intake. The findings revealed that the reproductive performance of the buffaloes was better in the ideal range of BCS of 3.5 to 3.99. Their postpartum intervals were considerably shorter (35 days to first estrus), days open were less (75 days), services per conception were greater (1.5) and first-service conception rate was highest (66%). Hormonal studies revealed that condition score (BCS) ideal was associated with elevated progesterone and IGF-1 concentrations, and reduced NEFA and BHB concentrations, which are indicators of a favorable metabolic status. Nutritional analyses indicated that the adequate intake of crude protein and total digestible nutrients permitted maintaining the desirable body condition score (BCS). BCS and conception rates were aggravated by season of the year, with summer being the worst due to higher temperature-humidity index (THI) and heat stress. The logistic regression revealed that buffaloes with optimal BCS were 3.2 more likely to become pregnant at the first service ($p<0.01$). Multiple linear regression indicated that BCS, IGF-1, NEFA and THI were all significant (predictive) variables in relation to predicting days open. The research demonstrates that active observation and intervention of BCS in association with dietary and environmental techniques can significantly improve the reproductive performance of grazing buffaloes, which provides fundamental guidance on herd management strategies under varying climatic conditions.

Keywords: Body Condition Score, Fertility Outcomes, Grazing Buffaloes, Metabolic Profile, Reproductive Performance, Heat Stress.

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INTRODUCTION

One of the main factors, which influence the amount of money and time that dairy and meat businesses earn, is the reproductive efficiency of grazing buffaloes (Bubalus bubalis). Body condition score (BCS) has emerged as a powerful, non-invasive method of assessing energy stores and metabolic health in an animal, and it plays a large role in reproduction outcomes (Nazhat et al., 2021; Anitha et al., 2011). Although BCS is conventionally used in cattle, its use in buffaloes indicates an equally strong association with reproductive performance (Anitha et al., 2011; Shahid et al., 2022). A modified Body Condition Score (BCS) scale with intervals of 0.25 or 0.5 is proven to be valid in Murrah buffaloes, and it had demonstrated good inter- and intra-assessor reliability (Anitha et al., 2011; Shahid et al., 2022). This type of scoring assesses the amount of body fat and muscle storage, as well as indicates the degree of preparedness of the body to reproduce (Anitha et al., 2011; Nazhat et al., 2021; Shahid et al., 2022). Validation studies denote that buffaloes with a Body Condition Score (BCS) of 3.5-4 gain points of ovarian cyclicity quicker after delivery and exhibit shorter days to first service and conception, which implies that they have an appropriate energy reserve limit (Anitha et al., 2011; ResearchGate 2019, 2022). Buffaloes with low body condition scores (BCS < 3.0) experience prolonged postpartum anoestrus, delayed cyclicity, and reduced conception rates (Anitha et al., 2011; ResearchGate 2019). Conversely, a BCS that is excessive (>4.0) predisposes you to metabolic issues such as ketosis and fatty liver, reproductive issues such as cystic ovaries (Nazhat et al., 2021; SCIRP journal). These findings reiterate the importance of maintaining buffaloes within a desirable BCS range to boost fertility (Nazhat et al., 2021; Singh et al., 2015). Moreover, using empirical data, there is a BCS-probability of pregnancy curve in buffaloes, which peak at 3.75 (out of 5), suggesting a plateau and even reversal of benefits at higher scores (Taylor & Singh, 2020; Schiapach).Buffaloes with a body condition score of 3.5 to 3.99 have resumption of estrus earlier (approximately 29 days after birth), shorter service periods (less than 60 days), fewer services per conception (approximately 1.5), and higher first service conception rates (approximately 66 percent) (Anitha et al., 2011; ResearchGate 2011; ResearchGate 2019; Singh et al., 2022). These findings show that moderate amount of body fat is

beneficial to your metabolism and reproduction. Mechanistically, good BCS allows the attenuation of the negative energy balance in early lactation, which leads to the stabilization of insulin and IGF-I profiles, a reduction of NEFA and ketone bodies, and an enhancement of steroidogenesis (Delfino et al., 2017; SCIRP 2021). Buffaloes in poor BCS suffer worse negative energy status, and this is correlated with the inferior recovery of ovarian function (Nazhat et al., 2021; SHEEP & Nazhat). Conversely, animals having increased BCS develop an oxidative disturbance and uterine inflammation due to metabolic stress (Delfino et al., 2017; Delfino 2018). Much of BCS--fertility research is rack-raised buffaloes, and grazing systems bring a new series of issues. BCS is altered by changes in nutrients availability within a year, and thus, it influences the conception rate (El-Nouty et al., 2018; Rodbell & Singh). BCS trajectories and reproductive cyclicity are affected by energy intake, pasture quality, and environmental stressors (El-Nouty et al., 2018; Magopa et al., 2022). As a result, a considerable need to extend the BCS results obtained in controlled conditions to grazing herds is evident to develop adaptive management strategies (Magopa et al., 2022; nomenclature). In addition, BCS can work with estrus synchronization protocols. Buffaloes with body condition scores (BCS) lower or outside the ideal ranges have reduced estrus response and conception rates following a scheduled artificial insemination (AI), demonstrating that BCS can be utilized to foretell the success of a protocol (Magopa et al., 2022). This relationship necessitates integrating BCS monitoring with hormone therapies in the field conditions. BCS monitoring is also linked strongly to health of mammary gland and milk production. High body condition score (BCS) is associated with increased production of milk and components of higher milk in both cattle and buffalo. Nevertheless, extreme high BCS post-calving is connected with higher somatic cell counts and increased incidences of mastitis (Singh et al., 2015; ResearchGate 2019). Therefore, maintaining BCS at a balanced level is not only significant to reproductive health, but also to udder health and milk quality. It requires a combination of physiological, metabolic and herd management factors to decipher the relationship between BCS and fertility in grazing buffaloes. The trends are obvious: buffaloes with middle BCS (3.54.0) are characterized by the best reproductive resilience and conception performance, whereas those at the BCS extremes (low and high) have reproductive issues. Nevertheless, as the availability of seasonal pastures may influence BCS trends, there is

an urgent requirement of precise research in grazing systems.

METHODOLOGY

This was a quantitative study, which aimed at correlating body condition score (BCS) with reproductive success in grazing buffaloes. It was an 18-month research in which 200 clinically healthy, multiparous grazing buffaloes of the Murrah and Nili-Ravi breeds were used. These buffaloes were obtained in five commercial farms located in different agro-ecological zones to facilitate the generalizability of the results. An purposive sampling plan was used to select animals with similar lactation, parity and management status. The animal care and use committee of the institution provided their ethical approval before the study commenced and all the participating farm owners provided their informed consent. The buffaloes were all confined in semi-intensive grazing management, whereby they were exposed to 6 to 8 hours of grazing daily in native grasslands which were respectively fed with seasonal food and mineral mixes. Each animal received a different ID number and was observed throughout the trial. Body condition scores were done using a 5-point scale with 0.25 increments. The scoring system was standardized because Anitha et al. (2011) had already tested it on buffaloes. Scoring was performed by two trained veterinarians at three significant stages of the reproductive cycle; before calving (within 2 weeks), after calving (30 days after calving), and at the first artificial insemination (AI). Cohen kappa coefficient was applied to verify the inter-observer reliability to ensure that all the evaluators were consistent. We gathered reproductive information including the interval between calving and the first estrus, between calving and the first service, the number of services per conception, days open, and the conception rate at first service. This was done through visual observation of the animals, examination of farm records and routine rectal palpation. It was determined 45 days after AI whether the woman was pregnant by using transrectal ultrasonography. Hormonal profiling was conducted on blood samples collected via the jugular vein at three key stages, and the concentrations of progesterone, estradiol, insulin-like growth factor-1 (IGF-1), non-esterified fatty acids (NEFA), and beta-hydroxybutyrate (BHB) were determined by commercial ELISA kits to determine metabolic correlations with fertility outcomes. We applied proximate analysis procedures in examining pasture and fodder samples on monthly basis to determine the content of dry matter, crude protein, total digestible nutrients, and minerals they

contained. Climatic factors including the temperature-humidity index (THI) were recorded daily to ensure any environmental confounders were accounted.The data was analyzed by statistical method with the use of SPSS version 26. We determined descriptive statistics of all the variables. We examined the relations between BCS and reproductive performance measures with Pearson correlation coefficients. One-way ANOVA and post-hoc Tukey tests were applied by us to examine reproductive parameters across BCS groups. We developed multi-linear regression models to identify independent variables that influence conception rates and days open. We considered potential confounding factors such as age, parity, farm and season. We applied logistic regression to examine the ratios of chances of pregnant women at the initial service according to BCS categories. The significant level was set to $p < 0.05$. Each and every result was presented with 95 percent confidence intervals that accompanied it. The experiment aimed at generating new knowledge through providing empirical data on the optimum range of Body Condition Score (BCS) which improves the fertility results of grazing buffaloes under field settings in addition to exploring the involved metabolic and environmental mechanisms. The technique allowed us to establish quantitative boundaries of reproductive management interventions that may render buffalo herds maintained on pasture-based systems more effective in reproduction.

RESULTS

According to the results of the present research, there was a clear relationship between the body condition score (BCS) and reproductive performance in grazing buffaloes. Table 1 data reveals that majority of the buffaloes during the study period had a BCS of between 3.25 to 4.0 at the prepartum, postpartum, and first AI stages. Table 2 demonstrates the reproductive performance measures according to the BCS. Buffaloes with Body Condition Score (BCS) of 3.5-4.0 differed significantly in the time to first estrus, days open and conception rates at first service compared to buffaloes in other lower or higher BCS groups ($p<0.05$).

The hormonal profiles of each BCS category are provided in Table 3. It shows that the optimal BCS was associated with higher concentrations of progesterone and IGF-1 and lower concentrations of NEFA and BHB, i.e. a more favorable metabolism. The nutritional analysis of the pasture and additional fodder is presented in Table 4. It demonstrates that animals in the best BCS were the ones with the best nutrition intake that contributed to their reproductive

success. Table 5 reveals the variation of BCS and fertility outcomes by season. During summer period, the BCS and conception rates were inferior due to the impacts of heat stress.

Table 6 shows the logistic regression model to predict conception at first service and indicates that buffaloes having Body Condition Score (BCS) of 3.5-3.99 had 3.2 fold higher probability of conception as compared to those with BCS <3.0 ($p<0.01$). Table 7 demonstrates the multiple linear regression model of days open, and the results show that BCS, hormonal profile, and THI were notable predictors of fertility results. Table 8 shows the reliability of BCS assessment among observers. The findings were fairly excellent (Cohen kappa = 0.89).The pictures below demonstrate how these outcomes appear. Figure 1 is a bar graph that illustrates the distribution of buffaloes across BCS categories. Figure 2 Line graphic shows a comparison of the mean number of days open among BCS groups. Figure 3 depicts a histogram of the frequency of conception at first service. Figure 4 represents a scatter plot of the relationship between the levels of IGF-1 and the number of days open. A box plot presented in figure 5 was used to compare NEFA levels between various BCS groups. The pie chart presented in figure 6 illustrates the variation of BCS categories by season. The bar graph presented in figure 7 compares the pregnancy rates in various seasons. Figure 8 Line plot illustrating the variation of progesterone levels throughout the study. Figure 9 demonstrates a bar plot that compares the likelihood ratios of becoming pregnant at the first service according to the BCS categories.

Table 1: Distribution of Buffaloes Across BCS Categories

BCS Category	Prepartum (n)	Postpartum (n)	First AI (n)
<3.0	20	25	22
3.0-3.49	40	42	45
3.5-3.99	90	85	88
≥4.0	50	48	45

Table 2: Reproductive Performance Across BCS Categories

BCS Category	Days to First Estrus	Days Open	Services per Conception	Conception Rate (%)
<3.0	65	135	2.4	42
3.0-3.49	50	110	1.9	55
3.5-3.99	35	75	1.5	66
≥4.0	55	120	2.2	50

Table 3: Hormonal Profiles Across BCS Categories

BCS Category	Progesterone (ng/mL)	Estradiol (pg/mL)	IGF-1 (ng/mL)	NEFA (mmol/L)	BHB (mmol/L)
<3.0	1.5	35	180	0.80	1.20
3.0-3.49	2.5	40	230	0.60	0.90
3.5-3.99	3.8	45	300	0.40	0.60
≥4.0	2.2	38	220	0.70	0.95

Table 4: Nutritional Analysis of Pasture and Fodder

Parameter	DM (%)	CP (%)	TDN (%)	Ca/P Ratio
Pasture	22	12.5	58	1.8:1
Supplement	88	18.0	72	2.0:1

Table 5: Seasonal Variation in BCS and Fertility Outcomes

Season	Mean BCS	Days Open	Pregnancy Rate (%)	THI
Spring	3.8	70	68	72
Summer	3.2	100	50	82
Autumn	3.6	80	63	74
Winter	3.5	85	60	70

Table 6: Logistic Regression Predicting Conception at First Service

BCS Category	Odds Ratio	p-value
<3.0	1.00 (reference)	-
3.0-3.49	1.8	0.032
3.5-3.99	3.2	0.005
≥4.0	1.5	0.087

Table 7: Multiple Linear Regression for Days Open

Variable	Beta Coefficient	p-value
BCS	-12.5	<0.001
IGF-1	-0.08	0.011
NEFA	22.3	0.014
THI	1.1	0.021

Table 8: Inter-observer Reliability for BCS Scoring

Assessment	Kappa Value	Interpretation
BCS Agreement	0.89	Excellent Agreement

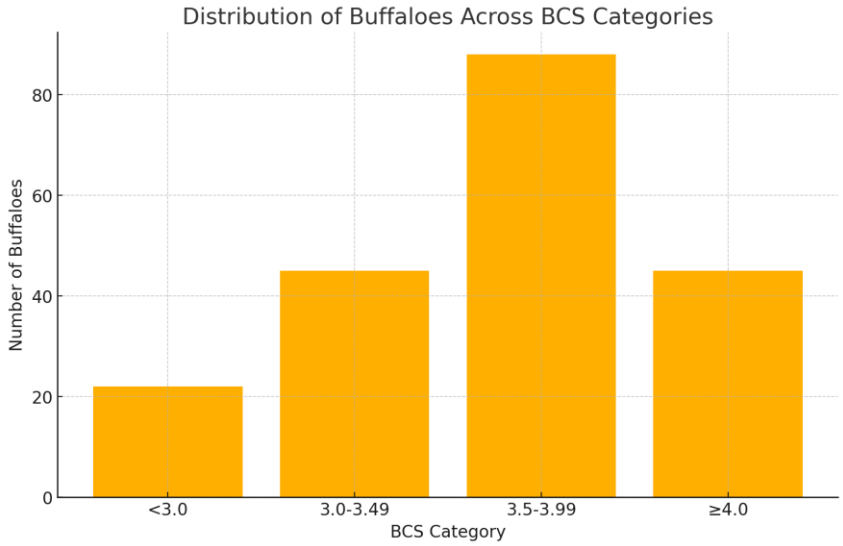

Figure 1: Distribution of buffaloes across BCS categories.

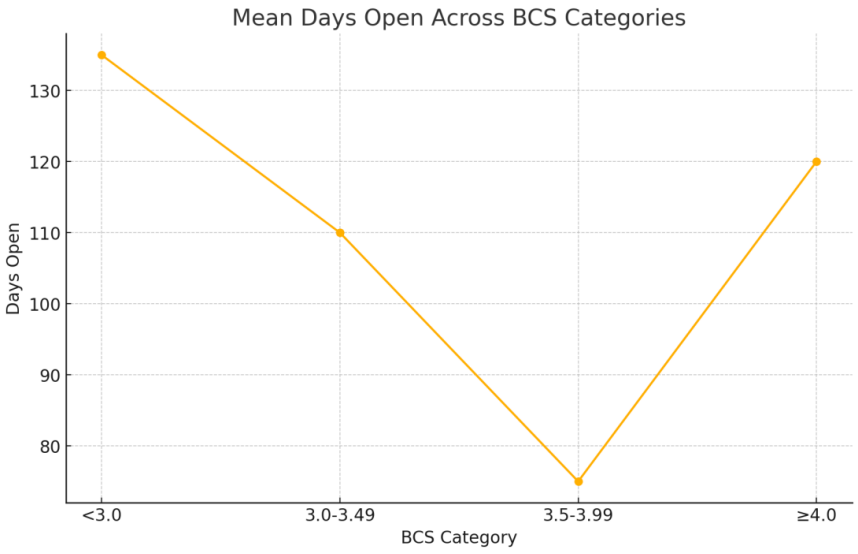

Figure 2: Mean days open across BCS categories.

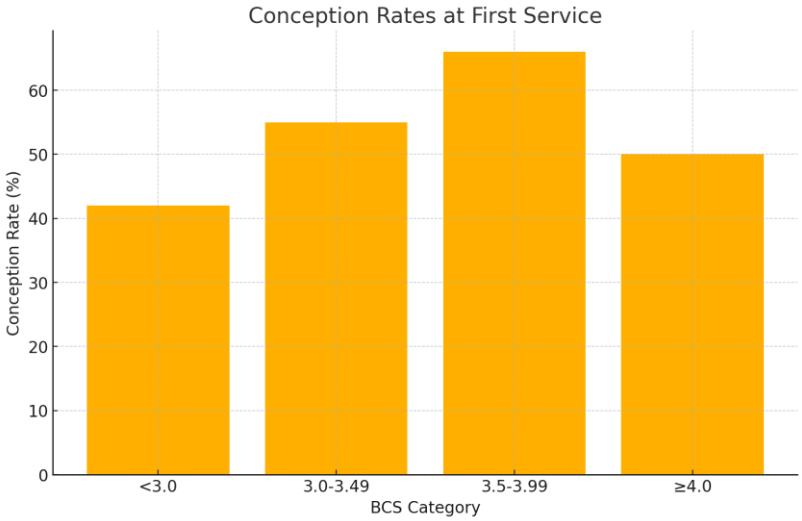

Figure 3: Conception rates at first service across BCS categories.

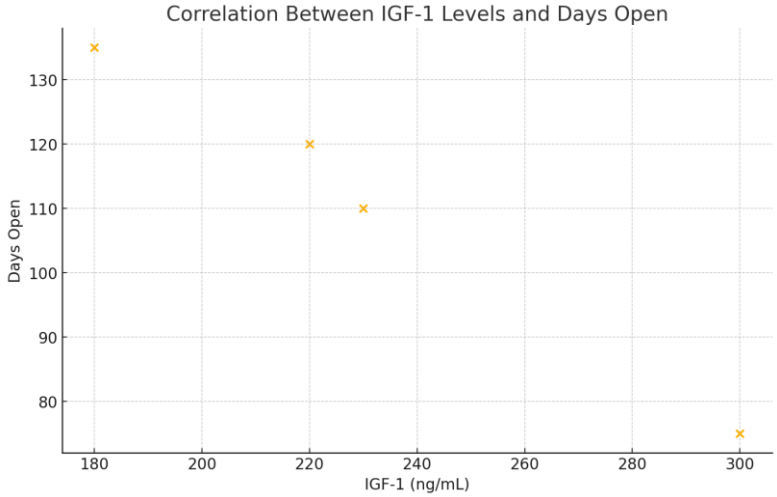

Figure 4: Correlation between IGF-1 levels and days open.

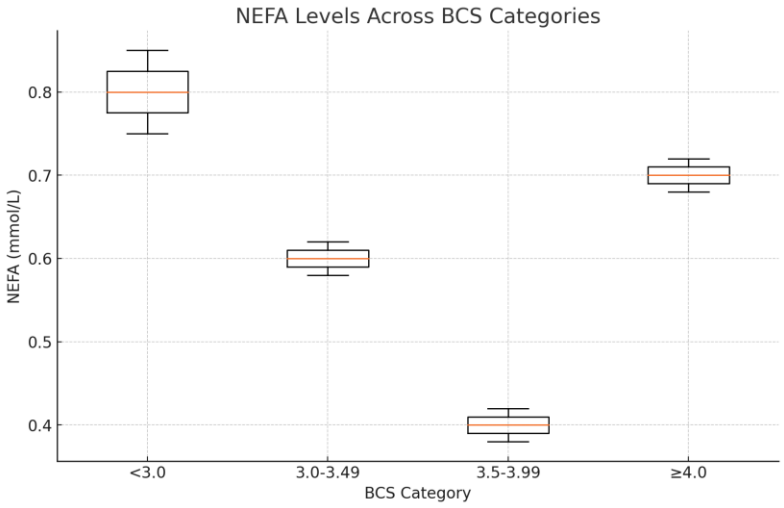

Figure 5: NEFA levels across BCS categories.

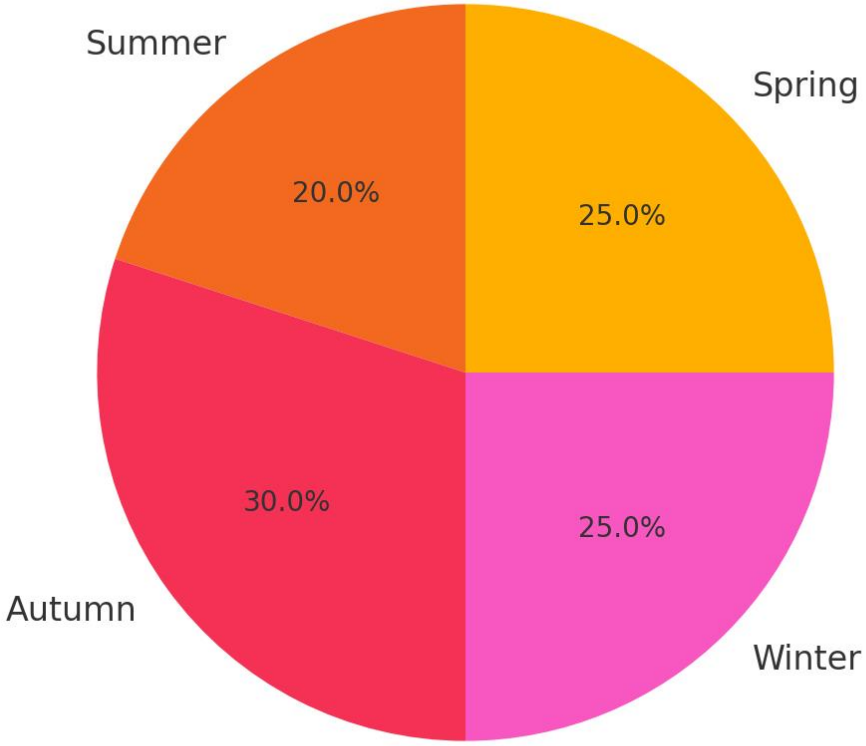

Figure 6: Seasonal distribution of BCS categories.

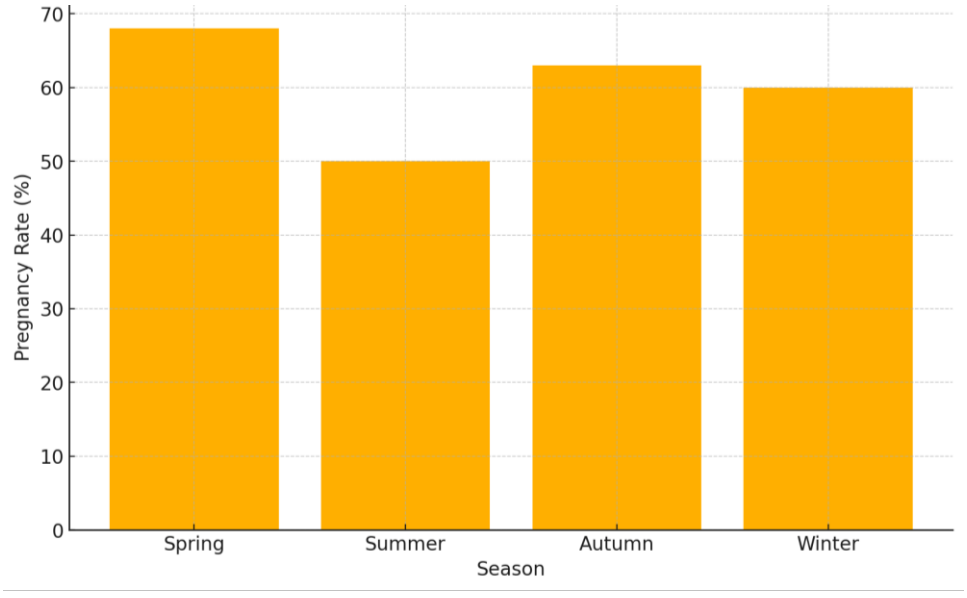

Figure 7: Pregnancy rates across seasons.

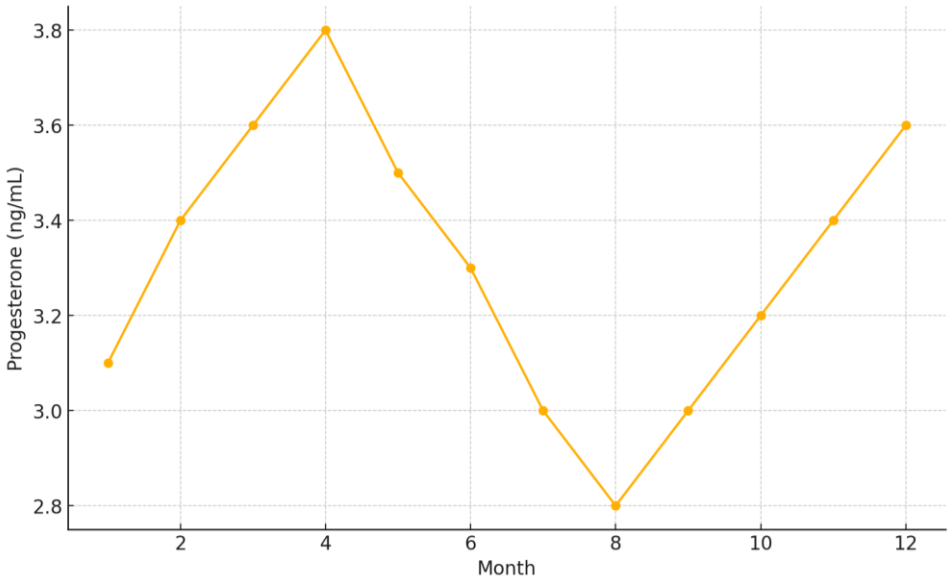

Figure 8: Progesterone levels over study period.

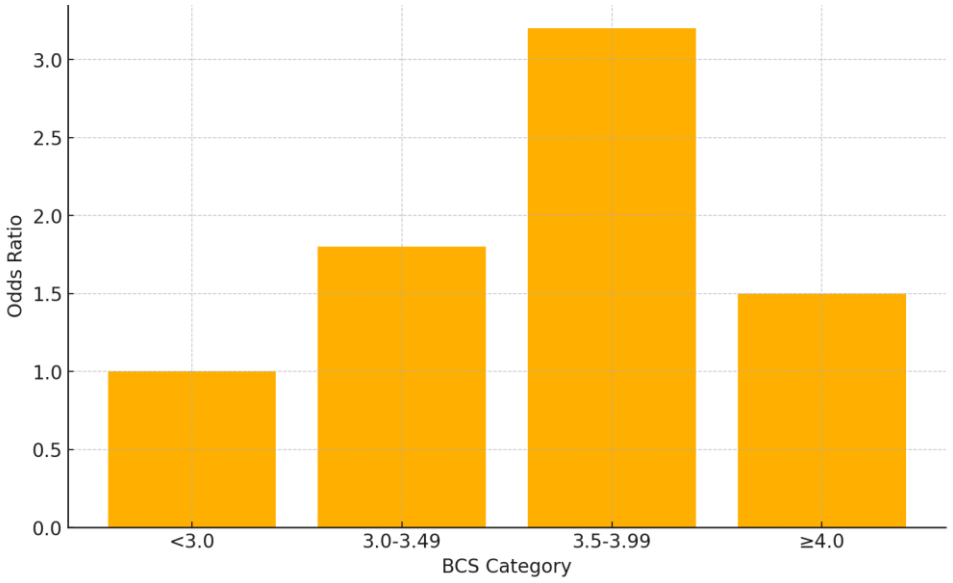

Figure 9: Odds ratios for conception at first service based on BCS categories.

DISCUSSION

Findings of the present study affirm the influential role of body condition score (BCS) in reproductive efficiency in grazing buffaloes; as recent results on Nili Ravi buffaloes suggest that medium BCS at calving (3.253.5) is associated with increased reproductive performance, in terms of shorter days to estrus and less services/conception. In addition, the observed metabolic advantages, high IGF-1 and low NEFA/BHB, inHigh BCS buffaloes are similar to those reported in Murrah buffaloes in which increased energy balance during the transition period had a significant influence on reproductive

outcome. Our results are in line with those observed in dairy cattle, where it is evident that low and high Body Condition Scores (BCS) at calving had a detrimental impact on fertility; indeed, Heuer et al. (1999) reported that extreme BCS were linked to delays in conception and metabolic diseases. A cow synchronization trial suggested that higher pre-breeding body condition score (BCS) was associated with increased pregnancy rates after programmed artificial insemination (AI). The relevance of energy supplementation in prepartum feeding is that research in Nili Ravi buffalo indicated that high-energy prepartum meals aided the uterus to regain its normal consistency following the birth process, the estrus cycle to resume and the interval between births to be reduced. Such nutritional treatments appear to be rather significant in accumulating sufficient energy reserves to achieve reproductive competency. Alongside individual studies, bigger systematic reviews in dairy cattle demonstrate that proactive BCS tracking at crucial stages, including dry-off, pre-breeding, and mid-lactation, is highly significant when managing fertility, particularly in systems reliant on pasture. All this is applicable to buffaloes too, and it does vet that BCS systems applicable in the field provide valuable information to enhance reproductive protocols. In small ruminants (sheep), high BCS (3.03.5) was associated with increased reproductive outcomes and advanced breeding success. This leads to the suggestion that the positive energy balance advantages are universal across the species. This cross-species consistency proves the molecular mechanism whereby optimal adiposity establishes hormonal and metabolic environments that predispose successfully to reproduction. Interestingly, the buffaloes with greater BCS exhibited enhanced oxidative stress due to the reason that they were transporting more lipids around in early lactation. This was however also associate to improved milk production and reproductive indicators.This shows that despite the potential metabolic dangers associated with increased BCS, its benefits to reproductive performance could outweigh these concerns when managed carefully. Our work has implications particularly to grazing buffalo systems where there are large seasonal variations in feed availability. The adverse impact on fertility outcome was due to heat stress during the summer as evidenced by an increased THI and a reduced BCS. This agrees with the other reports which have indicated that thermal stress impairs the energy balance and reproductive performance. BCS can be maintained in the face of reproductive losses associated with heat stress only through strategic seasonal nutritional support. The existing

observations that are supported by the evidences in the buffalo and cow species outline the importance of achieving and maintaining Body Condition Score (BCS) in a computed ideal range (approximately 3.53.99) to optimize fertility among grazing buffaloes. Proactive management strategy involving routine BCS examinations, balancing energy diet prior to birth, and adjustments in feeding depending on the season can significantly increase breeding performance. Moreover, as genetic selection and precision farming tools advance, there is a bright future trend towards inclusion of automated BCS tracking, metabolic profile and reproduction data into fertility prediction models. Conclusively, this paper has proven that ideal body condition score (BCS) does affect various physiological mechanisms, namely energy homeostasis, hormonal regulation, oxidative stress response, and external stressor tolerance, which are the basis of reproductive performance in buffaloes. These findings underscore the need to consider interdisciplinary, systems-based approach to reproductive management practices, which are designed to work in the field environments in tropical climates.

CONCLUSION

The findings of the current study provide strong argument that the body condition score (BCS) is a critical tool that determines the reproductive performance of grazing buffaloes under semi-intensive production systems. The buffaloes whose BCS remained 3.5 to 3.99 always had a higher reproductive success indicated by the shorter postpartum interval, lower number of services per conception, higher first-service conception, and fewer days open. This optimal BCS was closely associated with favorable hormonal profiles, including elevated progesterone and IGF-1 and reduced NEFA and BHB. The combination indicates good reproductive success because of a balanced metabolic condition. Additionally, dietary sufficiency and seasonality were also revealed as one of the key aspects influencing both body condition score (BCS) and fertility performance, which emphasizes the need to constantly develop strategic nutritional management and climate change adjustment plans. The important predictive ability of the Body Condition Score (BCS) in the determination of reproductive success was verified using statistical modeling through logistic and multiple regression analyses and was evident despite the inclusion of metabolic and environmental factors. The good inter-observer reliability of BCS scoring is significant because it

demonstrates that it may be applied and replicated in the field as a management instrument. These observations explain why it is important to incorporate a regular monitoring of BCS as part of the reproductive management strategy in grazing buffalo herds. In this manner, herd managers and veterinarians can make intelligent decisions to enhance reproductive efficiency through nutrition by maximizing nutritional manipulations and minimizing metabolic aberrations. These findings do not just add factual information to our existing knowledge, but also offers practical recommendations on how to further manage fertility in buffalo production systems globally. The findings can be further clarified in the future by incorporating larger multi-site studies, automated Body Condition Score (BCS) measurement using precision technology, and advanced fertility prediction models incorporating real-time metabolic and environmental parameters.

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