



# Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.045>

## EFFECT OF MATERNAL SUCKLING AND ASSISTED NEONATAL CARE ON PERFORMANCE, BEHAVIOURAL ADAPTATION, PASSIVE IMMUNITY AND NEONATAL PHYSIOLOGICAL STATUS OF INDIGENOUS SONADI LAMBS

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(Date of Receiving-22-05-2026; Date of Revision-28-07-2026; Date of Acceptance-15-08-2026)

### ABSTRACT

The present study assessed the effects of maternal suckling (MS) and assisted neonatal care (ANC) on growth performance, behavioural adaptation, passive immunity and neonatal physiological status in indigenous Sonadi lambs maintained under intensive management conditions. Fifty healthy singleton lambs (23 males and 27 females) were randomly assigned to MS (n = 25) or ANC (n = 25) groups immediately after birth. Lambs in the MS group remained continuously with their dams and suckled naturally, whereas ANC lambs received maternal colostrum by bottle feeding immediately after birth, followed by natural suckling with their dams. Colostrum intake during the first 24 h was kept at approximately 10% of body weight. Body weight and weekly weight gain were recorded up to 12 weeks of age. Behavioural observations were conducted during the first seven days postpartum, while hematobiochemical and immunological parameters were assessed at birth and 24 h postpartum. Maternal suckling lambs exhibited significantly higher body weight and weekly weight gain during most weeks of the study ( $P < 0.05$ ). Suckling frequency, suckling duration, walking activity, exploratory behaviour and ewe-lamb bonding were significantly higher in the MS group, whereas resting behaviour was greater in ANC lambs ( $P < 0.05$ ). At 24 h postpartum, MS lambs showed higher haemoglobin, packed cell volume, albumin, globulin, total protein, IgG and IgM concentrations than ANC lambs ( $P < 0.001$ ). The findings indicate that maternal suckling favours growth, behavioural adaptation and passive immunity in Sonadi lambs.

**Key words :** Sonadi sheep, Maternal suckling, Assisted neonatal care, Behaviour, Passive immunity, Growth performance.

### Introduction

Sheep husbandry is an essential part of the livestock industry in Rajasthan and significantly contributes to the livelihoods of pastoralists and smallholder farmers in both arid and semi-arid areas. As per the 20th Livestock Census of India, which was carried out by the Department of Animal Husbandry and Dairying, Government of India, the total sheep population in the country was recorded at 74.26 million (Government of India, 2019).

Rajasthan ranks among the leading states for sheep rearing, boasting an estimated population of 7.9 million sheep, which highlights the significance of small ruminants in the state's agrarian economy (Government of India,

2019; Sharma *et al.*, 2029).

Among the indigenous breeds recognized in Rajasthan, the Sonadi sheep holds particular significance due to its ability to adapt to the hot, arid climatic conditions and low-input production systems that are common in southern Rajasthan. The Sonadi breed is primarily found in the districts of Udaipur, Dungarpur, Banswara, Chittorgarh and Rajsamand, where it is mainly raised for meat and coarse wool production (Gowane *et al.*, 2016; FAO, 2012).

Population estimates by breed suggest that the pure Sonadi sheep population is around 0.158 million, representing approximately 1.7% of Rajasthan's total

sheep population, alongside an additional number of graded or non-descript Sonadi-type sheep that farmers maintain under extensive systems (Gowane *et al.*, 2016 and Kumar *et al.*, 2021).

Neonatal survival and early-life adaptation are essential factors influencing productivity and welfare in sheep production systems. The neonatal phase is marked by swift physiological, behavioural, and immunological changes that have a direct impact on lamb growth, survival rates, disease resistance, and long-term productivity (Poindron *et al.*, 1993; Dwyer, 2014; Jenvey *et al.*, 2014). Among the various management aspects that influence neonatal development, nursing practices are crucial for ensuring sufficient colostrum intake, fostering ewe-lamb bonding, facilitating passive immunity transfer, and promoting behavioural adaptation in early life (Napolitano *et al.*, 2010).

Maternal colostrum is the main source of immunoglobulins, nutrients, growth factors, and bioactive substances essential for the survival and immune competence of neonatal lambs (Mellor and Stafford, 2004). Given that the transfer of immunoglobulins through the placenta is minimal in sheep, lambs are born essentially without antibodies and rely completely on prompt colostrum consumption for passive immune defence (Piccione *et al.*, 2010; Yang *et al.*, 2025). Inadequate passive transfer can make neonatal lambs more susceptible to infectious diseases, hinder their growth, and lead to higher rates of morbidity and mortality (Hernandez-Castellano *et al.*, 2014). Consequently, effective early nursing management is regarded as one of the most vital aspects of successful lamb rearing practices.

Natural maternal suckling guarantees a steady supply of colostrum and promotes behavioural adaptation through maternal grooming, suckling stimulation, and the formation of ewe-lamb bonds (Dwyer and Lawrence, 2005). Effective maternal interaction enhances neonatal vigor, thermoregulation, feeding behaviour, and stress adaptation in lambs (Nowak and Poindron, 2006; Dwyer *et al.*, 2016). Lambs that lack unrestricted maternal contact may show delayed behavioural adaptation, decrease suckling efficiency, and hinder physiological adjustment in their early life (Hernandez-Castellano *et al.*, 2015a).

In intensive sheep production systems, practices for assisted neonatal care, including bottle feeding, regulated colostrum administration and additional neonatal management, are commonly implemented to enhance neonatal monitoring and decrease lamb mortality (Dwyer, 2008). While, these practices may enhance management

efficiency, they can disrupt the natural interactions between ewes and lambs, which may subsequently affect behavioural adaptation, stress responsiveness, and immune development in lambs (Napolitano *et al.*, 2008).

Growth performance observed in the pre-weaning phase is closely linked to early nutrition, nursing behaviour, and immune health. Lambs that receive sufficient maternal milk and colostrum typically show enhanced body weight gain, feed efficiency, and survival rates (Alves *et al.*, 2015). Additionally, the passive immunity obtained from colostrum plays a significant role in bolstering disease resistance and overall health during the neonatal period (Hernandez-Castellano *et al.*, 2015b).

Sonadi sheep is a significant indigenous breed found in Rajasthan, which is well-suited to semi-arid climatic conditions and is highly regarded for its meat production and the security it provides to rural livelihoods (Sharma *et al.*, 2019). Therefore, the present study was undertaken to evaluate the effect of maternal suckling and assisted neonatal care on growth performance, behavioural adaptation, passive immunity and neonatal physiological status in indigenous Sonadi lambs maintained under intensive management conditions. It was hypothesized that differences in neonatal management practices during the immediate postnatal period may influence growth, immune competence and physiological adaptation, even when maternal colostrum and maternal milk constitute the primary source of nutrition in both management systems.

## Materials and Methods

### Ethical statement

All animal procedures and experimental protocols were conducted in strict compliance with the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA). Prior approval was obtained from the Institutional Animal Ethics Committee (IAEC) of CVAS Navania, Udaipur, Rajasthan University of Veterinary and Animal Sciences (RAJUVAS), Bikaner (Approval No. IAEC/RES/05/06). Careful measures were consistently implemented throughout the study to minimize stress and discomfort to the experimental animals, and all management and handling practices adhered to established animal welfare standards.

### Study location

The present study was conducted under intensive management conditions at the Network project on Sheep improvement (NWPSI, Sonadi Unit), College of Veterinary and Animal Science (CVAS), Navania,



**Fig. 1 :** Geographical location of the study site at CVAS Navania, Vallabhnagar, Udaipur.

Vallabhnagar, Udaipur, under the Rajasthan University of Veterinary and Animal Sciences (RAJUVAS), Bikaner. The geographical location of the study site is illustrated in the map below (Fig. 1).

### Experimental animals

A total of fifty healthy indigenous Sonadi lambs, born during the experimental period, were selected for this study. All lambs involved in the experiment were singleton births. The group consisted of 23 males and 27 females, which were randomly assigned to one of two neonatal nursing management systems immediately after birth. The maternal suckling (MS) group included 25 lambs, comprising 11 males and 14 females, while the assisted neonatal care (ANC) group also consisted of 25 lambs, with 12 males and 13 females.

Throughout the study period, all ewes and lambs were kept under intensive management conditions. The two treatment groups were housed separately in clean, dry, and well-ventilated pens that provided sufficient space, proper drainage and regular sanitation. Fresh drinking water was available *ad libitum*. During the experimental period, neither ewes nor lambs had access to grazing or pasture.

### Experimental design and neonatal nursing management

The study was designed to evaluate the effect of two neonatal nursing management practices, namely maternal suckling (MS) and assisted neonatal care (ANC), on growth performance, behavioural adaptation, passive immunity and neonatal physiological status of Sonadi lambs.

#### Maternal suckling group (MS)

Lambs allocated to the maternal suckling group remained continuously with their respective dams immediately after birth and throughout the neonatal period. The lambs were allowed unlimited natural suckling without any human interference. Colostrum intake occurred naturally according to the lamb's nursing behaviour and maternal availability. Routine farm management practices were followed in this group,

including regular health monitoring and hygienic maintenance of the housing environment.

#### Assisted neonatal care group (ANC)

Lambs assigned to the assisted neonatal care group also remained with their dams throughout the experimental period. However, immediately after birth, colostrum obtained from the respective dam was administered to the lamb by bottle feeding to ensure timely colostrum intake.

During the first 24 hours of life, the amount of colostrum provided was kept at around 10% of the lamb's body weight. After the initial administration of colostrum via bottle, lambs were permitted to suckle from their mothers naturally. In addition to the assisted feeding of colostrum, lambs in the ANC group benefited from improved neonatal care practices, which included disinfection of the umbilical cord with an antiseptic solution, recording of body weight, ear tagging for identification purposes, regular health assessments, and hygienic management. Throughout the study, no milk replacer or artificial milk substitute was utilized. Creep feed was introduced in accordance with standard farm practices to support a gradual transition from milk to solid feed.

### Growth performance

#### Body weight

Body weight of each lamb was recorded at birth using a calibrated digital weighing scale. Subsequently, body weights were noted weekly until the lambs attained 12 weeks of age, specifically in the morning before feeding to avoid variations due to gut fill.

#### Weekly weight gain

Weekly weight gain (WWG) was calculated as the difference between current and previous week body weights using the following equation:

$$\text{WWG (kg)} = \text{BW}_n - \text{BW}_{n-1}$$

Where,  $\text{BW}_n$  represents body weight at the current week and  $\text{BW}_{n-1}$  represents body weight at the previous week.

#### Behavioural observations

Behavioural observations were carried out during the initial seven days following lambing, utilizing the scan sampling technique as outlined by Martin and Bateson (2015). Daily observations were made during the morning (08:00–10:00 h) and evening (16:00–18:00 h) sessions. The behavioural traits evaluated, along with their operational definitions, are detailed in Table 1. Suckling frequency and duration were documented separately

**Table 1 :** Ethogram of behavioural traits recorded in Sonadi lambs during the neonatal period.

| Behavioural trait    | Definition                                                                                   |
|----------------------|----------------------------------------------------------------------------------------------|
| Suckling frequency   | Number of suckling bouts observed during each observation period                             |
| Suckling duration    | Total duration spent suckling during the observation period                                  |
| Walking activity     | Frequency of locomotor movements exhibited by the lamb                                       |
| Resting behaviour    | Time spent lying inactive or resting                                                         |
| Exploratory activity | Sniffing, investigating, or interacting with the surrounding environment                     |
| Vocalization         | Frequency of bleating or vocal sounds emitted by the lamb                                    |
| Ewe–lamb bonding     | Close affiliative interaction between ewe and lamb, including following and physical contact |

during both morning and evening observation periods to assess neonatal nursing behaviour, while locomotory and social behaviours were aggregated into daily observations for the purpose of statistical analysis. All behavioural observations were conducted by a single observer throughout the experimental duration to reduce observer bias.

Colostrum intake was not assessed directly; thus, the frequency and duration of early suckling were regarded as indirect measures of colostrum consumption and neonatal adaptation. The early suckling behaviour is widely acknowledged as a dependable indicator of effective colostrum intake and the transfer of passive immunity in neonatal lambs, as consistent and successful suckling signifies sufficient milk consumption and appropriate ewe-lamb bonding (Nowak and Poindron, 2006; Dwyer, 2008). Comparable methods have been confirmed in neonatal calves and piglets, where suckling behaviour has been linked to the efficiency of colostrum intake, passive immune transfer, and overall neonatal vitality (Godden, 2008; Vasseur *et al.*, 2010; Devillers *et al.*, 2011; Quesnel *et al.*, 2012). Consequently, suckling frequency and duration were utilized as the main indicators of early nursing efficiency in both experimental groups.

### Hematobiochemical and immunological and Analysis

Blood samples were aseptically obtained from the jugular vein of lambs immediately after birth, prior to colostrum intake and again 24 hours following colostrum feeding. Approximately 5 mL of blood was drawn into both EDTA-coated and plain vacutainer tubes for

subsequent haematological, biochemical and immunological evaluations.

Haematological parameters, including haemoglobin (Hb), packed cell volume (PCV) and total leucocyte count (TLC), as well as biochemical parameters such as total protein (TP), albumin and globulin were assessed using an automated blood analyzer in accordance with standard laboratory protocols. The concentration of globulin was determined by subtracting the albumin values from the total protein concentrations.

For the immunological evaluation, serum concentrations of Immunoglobulin G (IgG) and Immunoglobulin M (IgM) were measured using commercially available ELISA kits (Helix ELISA Kit), following the manufacturer's guidelines. Serum samples were isolated after centrifugation at 3000 rpm for 10 minutes and were stored at  $-20^{\circ}\text{C}$  until further analysis. All hematobiochemical and immunological assessments were conducted in the Department of Veterinary Physiology and Biochemistry and Veterinary Microbiology at CVAS Navania, Udaipur- RAJUVAS, Bikaner.

### Statistical analysis

All experimental data were gathered and analyzed utilizing R statistical software (R Core Team, 2024). Descriptive statistics, including mean and standard error (SE) were computed for all variables, with results presented as mean  $\pm$  SE.

Before conducting statistical analysis, the normality of the data distribution was assessed using the Shapiro–Wilk test, while the homogeneity of variances was evaluated through Levene's test. Body weight and weekly weight gain data, which consisted of repeated measurements on the same animals over time, were examined using a linear mixed-effects model with repeated measures. This model incorporated the neonatal nursing management system [Maternal Suckling (MS) and Assisted Neonatal Care (ANC)], sex (male and female), week of observation, and their interactions as fixed effects, while individual lamb was treated as a random effect to account for repeated observations within the same animal.

Behavioural observations such as suckling frequency, suckling duration, walking activity, resting behaviour, exploratory activity, vocalization and ewe–lamb bonding were documented during both morning and evening sessions, and the data were subsequently averaged for each lamb. The average values for each behavioural trait were analyzed between the two neonatal management groups using an independent samples Student's t-test. In

cases where the assumption of homogeneity of variance was not met, Welch's t-test was utilized.

Hematobiochemical parameters, which included haemoglobin (Hb), packed cell volume (PCV), total leucocyte count (TLC), albumin, globulin and total protein, along with immunological parameters such as immunoglobulin G (IgG) and immunoglobulin M (IgM), were measured at birth and again 24 hours post-birth. These parameters were analyzed using an independent samples Student's t-test to compare the means between the two neonatal nursing management systems. Differences in means were deemed statistically significant at  $P < 0.05$ , while  $P < 0.01$  was regarded as highly significant.

## Results

### Growth performance of Sonadi lambs

Weekly body weight responses of Sonadi lambs under maternal suckling (MS) and assisted neonatal care (ANC) systems are presented in Table 2.

At birth, the average body weight of lambs was similar between the two groups, with measurements of  $2.93 \pm 0.02$  kg for the MS group and  $2.99 \pm 0.02$  kg for the ANC group ( $P > 0.05$ ). Following this, body weight progressively increased with age in both neonatal management systems. Lambs that were suckled by their mothers showed significantly greater body weights than those receiving assisted neonatal care during the majority of the experimental weeks. Notable differences ( $P < 0.05$ ) were found at weeks 1 and 8, while highly significant differences ( $P < 0.01$ ) were noted during weeks 2–5, 7, and 10–12. No significant differences were detected at weeks 6 and 9. By the conclusion of the experimental period (week 12), lambs in the MS group achieved a significantly higher body weight of  $15.74 \pm 0.06$  kg compared to  $15.10 \pm 0.13$  kg in the ANC group ( $P < 0.01$ ).

The pattern of weekly weight gain (kg) is presented in Table 3. In week 1, lambs under maternal suckling showed a significantly higher weekly weight gain of  $0.30 \pm 0.02$  kg compared to  $0.26 \pm 0.03$  kg for those under assisted neonatal care ( $P < 0.05$ ). Lambs in the maternal suckling group continued to exhibit significantly higher weekly weight gains during weeks 2, 3, 4, 6, 7, 8, 10 and 12, while no significant differences were noted at weeks 5 and 11. Conversely, lambs receiving assisted neonatal care had a significantly higher weekly weight gain at week 9 ( $1.23 \pm 0.02$  kg) compared to those under maternal suckling ( $1.14 \pm 0.01$  kg) ( $P < 0.01$ ). The peak weekly weight gain was recorded in week 10 for the maternal

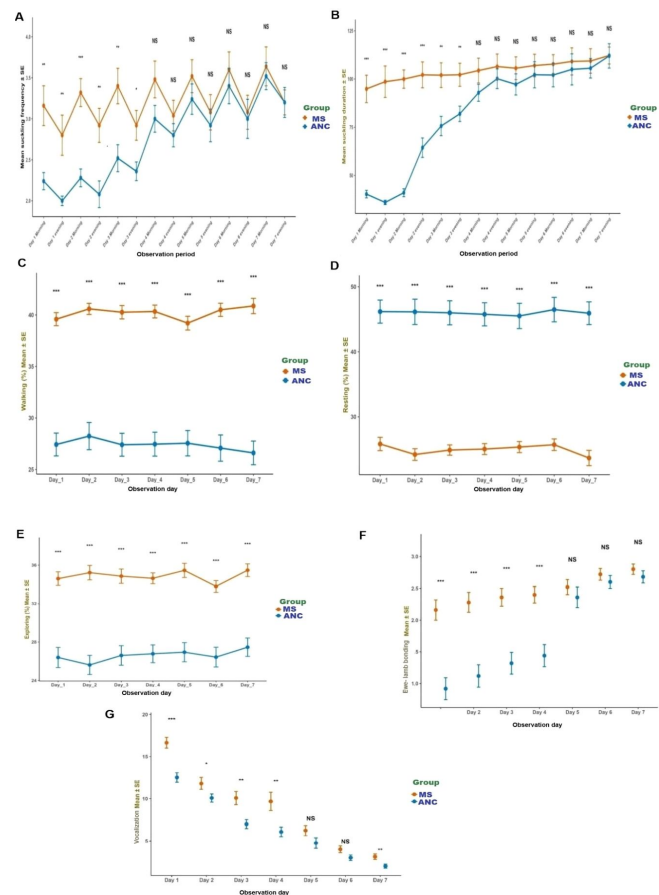


**Fig. 2 :** Daily behavioural observations of Sonadi lambs under maternal suckling (MS) and assisted neonatal care (ANC) management during the first seven postnatal days. (A) Suckling frequency; (B) suckling duration; (C) walking activity; (D) resting behaviour; (E) exploratory behaviour; (F) ewe-lamb bond score and (G) vocalization count. Values are expressed as Mean  $\pm$  SE. \*  $P \leq 0.05$ ; \*\*  $P \leq 0.01$ ; \*\*\*  $P \leq 0.001$ ; NS = non-significant.

suckling group ( $1.61 \pm 0.02$  kg), whereas the highest gain for the assisted neonatal care group occurred in week 9 ( $1.23 \pm 0.02$  kg). Overall, lambs raised through maternal suckling consistently exhibited greater body weight and weekly weight gain than those managed through assisted neonatal care for the majority of the experimental duration.

### Behavioural responses of Sonadi lambs

The behavioural responses of Sonadi lambs reared under maternal suckling (MS) and assisted neonatal care (ANC) during the first seven days postpartum are presented in Fig. 2.

During the initial three days following lambing, the frequency and duration of suckling were significantly higher in MS lambs. Notable to very highly significant differences ( $P < 0.05$  to  $P < 0.001$ ) were recorded during the morning and evening observations from Day 1 to Day

3, while differences became non-significant starting from Day 4, in both groups (Fig. 2A, B).

Walking behaviour exhibited considerable variation between the two nursing systems, with MS lambs consistently allocating a larger proportion of their observation time to locomotor activities than ANC lambs throughout the seven-day observation period (Fig. 2C). The mean walking activity for MS lambs ranged from 39.21 to 40.87%, in contrast to 26.61 to 28.24% for ANC lambs, with differences being highly significant on all observation days ( $P < 0.001$ ).

In contrast, resting behaviour was significantly more pronounced in ANC lambs than in MS lambs across all seven observation days ( $P < 0.001$ ). The resting activity for ANC lambs varied from 45.51 to 46.49% of total observation time, while MS lambs showed a range of 23.66 to 25.82% (Fig. 2D). Likewise, exploratory behaviour was consistently higher in MS lambs throughout the neonatal period, with mean values between 33.80 to 35.47% compared to 25.62 to 27.46% in ANC lambs. The differences remained highly significant during the entire observation period ( $P < 0.001$ ) (Fig. 2E).

Ewe–lamb bonding scores were markedly elevated in maternally suckled (MS) lambs during the early neonatal phase when compared to those receiving assisted neonatal care (ANC). Highly significant differences ( $P < 0.001$ ) were noted from Day 1 to Day 4, with MS lambs consistently demonstrating stronger maternal attachment and bonding behaviours. However, the differences became non-significant during Days 5–7, indicating a gradual adaptation and establishment of maternal interaction in both groups (Fig. 2F).

In a similar vein, the frequency of vocalizations was significantly higher in MS lambs during the early neonatal period. A very highly significant difference ( $P < 0.001$ ) was observed on Day 1, whereas significant to highly significant differences ( $P < 0.05$  to  $P < 0.01$ ) were recorded from Days 2 to 4 and again on Day 7. However, non-significant differences were observed on Days 5 and 6 (Fig. 2G).

### Hematobiochemical analysis

Hematobiochemical responses of Sonadi lambs under maternal suckling (MS) and assisted neonatal care (ANC) management are depicted in Fig. 3.

No significant differences were noted between the groups at birth regarding haemoglobin (Hb), packed cell volume (PCV), total leukocyte count (TLC), albumin, globulin, or total protein concentrations ( $P > 0.05$ ). At 24 hours post-lambing, MS lambs displayed significantly

**Table 2 :** Mean  $\pm$  SE weekly body weight (kg) of Sonadi lambs reared under maternal and assisted neonatal care management from week 0 to week 12 post-lambing. (n = 25/group).

| Week | Maternal nursing (MS) | Assisted neonatal care (ANC) | p-value | Sig. |
|------|-----------------------|------------------------------|---------|------|
|      | Mean $\pm$ SE         | Mean $\pm$ SE                |         |      |
| 0    | 2.93 $\pm$ 0.02       | 2.99 $\pm$ 0.02              | 0.055   | NS   |
| 1    | 3.48 $\pm$ 0.03       | 3.39 $\pm$ 0.03              | 0.034   | *    |
| 2    | 4.71 $\pm$ 0.03       | 4.50 $\pm$ 0.01              | <0.001  | **   |
| 3    | 5.88 $\pm$ 0.01       | 5.81 $\pm$ 0.01              | <0.001  | **   |
| 4    | 7.83 $\pm$ 0.04       | 7.63 $\pm$ 0.02              | <0.001  | **   |
| 5    | 8.11 $\pm$ 0.02       | 7.86 $\pm$ 0.02              | <0.001  | **   |
| 6    | 9.84 $\pm$ 0.06       | 9.69 $\pm$ 0.10              | 0.231   | NS   |
| 7    | 11.00 $\pm$ 0.02      | 10.73 $\pm$ 0.06             | <0.001  | **   |
| 8    | 12.23 $\pm$ 0.05      | 11.95 $\pm$ 0.12             | <0.05   | *    |
| 9    | 12.88 $\pm$ 0.09      | 12.63 $\pm$ 0.11             | 0.089   | NS   |
| 10   | 14.14 $\pm$ 0.10      | 13.45 $\pm$ 0.09             | <0.001  | **   |
| 11   | 14.93 $\pm$ 0.09      | 14.05 $\pm$ 0.11             | <0.001  | **   |
| 12   | 15.74 $\pm$ 0.06      | 15.10 $\pm$ 0.13             | <0.001  | **   |

\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ ; NS = non-significant. Week 0 represents body weight at birth.

elevated Hb and PCV values in comparison to ANC lambs ( $P < 0.001$ ). The haemoglobin concentration rose to  $11.26 \pm 0.08$  g/dL in MS lambs, whereas it was  $10.46 \pm 0.07$  g/dL in ANC lambs. Additionally, PCV values were recorded at  $33.57 \pm 0.18\%$  for MS lambs and  $31.91 \pm 0.24\%$  for ANC lambs, respectively (Fig. 3A).

The serum protein profile also exhibited significant differences between the groups at 24 hours following colostrum intake. MS lambs presented significantly higher concentrations of albumin, globulin, and total protein compared to ANC lambs ( $P < 0.001$ ). The total protein concentration in MS lambs increased to  $62.90 \pm 0.38$  g/L, in contrast to  $56.30 \pm 0.35$  g/L in ANC lambs, while globulin concentrations were  $30.75 \pm 0.30$  g/L and  $25.44 \pm 0.33$  g/L, respectively. Conversely, TLC values at 24 hours were significantly greater in ANC lambs than in MS lambs ( $P < 0.001$ ). In summary, lambs that were maternally suckled exhibited enhanced hematobiochemical responses following colostrum intake when compared to those raised under assisted neonatal care systems (Fig. 3B).

### Immunological and analysis

Immunoglobulin responses of Sonadi lambs under

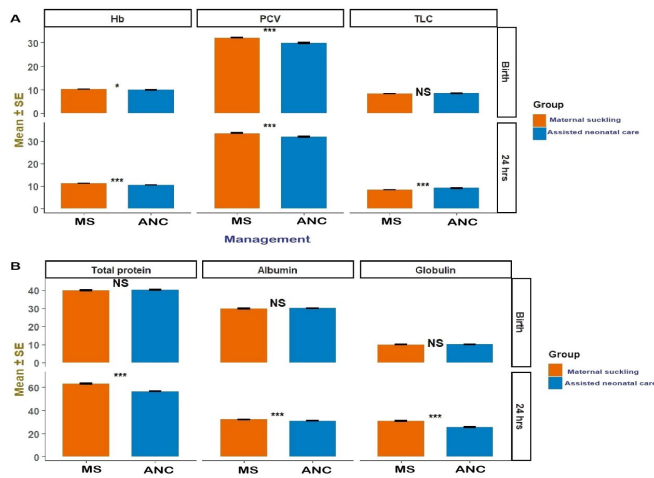


**Fig. 3 :** Comparative hematobiochemical (A, B) of Sonadi lambs under maternal suckling (MS) and assisted neonatal care (ANC) systems at birth and 24 h post-lambing, showing haemoglobin (Hb), packed cell volume (PCV), total leukocyte count (TLC), albumin, globulin, total protein. Values are expressed as Mean  $\pm$  SE. \*  $P \leq 0.05$ ; \*\*  $P \leq 0.01$ ; \*\*\*  $P \leq 0.001$ ; NS = non-significant.

**Table 3 :** Mean  $\pm$  SE weekly body weight gain (kg) of Sonadi lambs reared under maternal suckling and assisted neonatal care management from week 1 to week 12 post-lambing. (n = 25/group).

| Week | Maternal nursing (MS) | Assisted neonatal care (ANC) | p-value | Sig. |
|------|-----------------------|------------------------------|---------|------|
|      | Mean $\pm$ SE         | Mean $\pm$ SE                |         |      |
| 1    | 0.30 $\pm$ 0.02       | 0.26 $\pm$ 0.03              | 0.037   | *    |
| 2    | 0.46 $\pm$ 0.01       | 0.39 $\pm$ 0.01              | <0.01   | **   |
| 3    | 1.06 $\pm$ 0.01       | 0.85 $\pm$ 0.01              | <0.0001 | ***  |
| 4    | 0.79 $\pm$ 0.00       | 0.70 $\pm$ 0.01              | <0.001  | **   |
| 5    | 0.85 $\pm$ 0.07       | 0.72 $\pm$ 0.01              | 0.126   | NS   |
| 6    | 1.06 $\pm$ 0.02       | 0.88 $\pm$ 0.01              | 0.034   | *    |
| 7    | 1.32 $\pm$ 0.03       | 1.01 $\pm$ 0.01              | <0.0001 | ***  |
| 8    | 1.17 $\pm$ 0.02       | 0.99 $\pm$ 0.02              | <0.001  | **   |
| 9    | 1.14 $\pm$ 0.01       | 1.23 $\pm$ 0.02              | <0.001  | **   |
| 10   | 1.61 $\pm$ 0.02       | 1.04 $\pm$ 0.02              | <0.0001 | ***  |
| 11   | 1.23 $\pm$ 0.09       | 1.03 $\pm$ 0.09              | 0.151   | NS   |
| 12   | 1.41 $\pm$ 0.05       | 1.16 $\pm$ 0.08              | <0.001  | **   |

\*\*\*  $p \leq 0.001$ ; \*\*  $p \leq 0.01$ ; \*  $p \leq 0.05$ ; NS = non-significant.

maternal suckling (MS) and assisted neonatal care (ANC) systems are depicted in Fig. 4. At birth, no significant differences were noted between the groups regarding serum IgG and IgM concentrations ( $P > 0.05$ ), suggesting a comparable passive immune status immediately post-

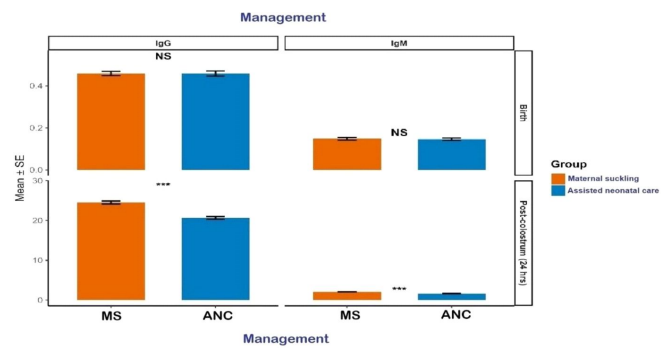


**Fig. 4 :** Immunological responses of Sonadi lambs under maternal suckling (MS) and assisted neonatal care (ANC) systems at birth and 24 h post-lambing, showing IgG and IgM concentrations. Values are expressed as Mean  $\pm$  SE. \*  $P \leq 0.05$ ; \*\*  $P \leq 0.01$ ; \*\*\*  $P \leq 0.001$ ; NS = non-significant.

birth. Nevertheless, significant post-colostral alterations were noted 24 hours after lambing. MS lambs showed considerably higher serum IgG and IgM concentrations in comparison to ANC lambs ( $P < 0.001$ ). The serum IgG concentration rose to  $24.50 \pm 0.33$  g/L in MS lambs, while ANC lambs had a concentration of  $20.62 \pm 0.67$  g/L. Likewise, the IgM concentration increased to  $2.08 \pm 0.035$  g/L in MS lambs, whereas ANC lambs recorded a concentration of  $1.61 \pm 0.039$  g/L.

## Discussion

### Growth performance

Growth during the neonatal and pre-weaning periods is considered one of the most important indicators of the adequacy of nursing management in lambs because it reflects nutrient intake, physiological adaptation and overall health status. In the present study, lambs reared under maternal suckling (MS) exhibited significantly greater body weight and weekly weight gain during most weeks of the experimental period compared with lambs managed under assisted neonatal care (ANC). Since both groups received maternal colostrum and maternal milk and remained with their dams throughout the study, the observed differences may be attributed primarily to differences in early nursing management and suckling behaviour rather than to differences in milk source.

The higher body weight and weight gain observed in the MS group may be associated with the immediate establishment of natural suckling behaviour and unrestricted access to the dam immediately after birth. Early and repeated suckling has been shown to enhance milk intake, stimulate gastrointestinal development and improve metabolic adaptation in neonatal lambs (Hernandez-Castellano *et al.*, 2019). Dwyer *et al.* (2016) reported that lambs establishing successful suckling soon

after birth exhibit improved growth and survival during the neonatal period. Likewise, Nowak and Poindron (2006) emphasized that uninterrupted maternal care facilitates early feeding behaviour and optimizes neonatal adaptation.

In the ANC group, although colostrum was derived from the respective dam and administered immediately after birth, bottle feeding and neonatal handling may have temporarily altered early suckling dynamics and maternal interaction. Such management-associated differences during the first hours of life could influence subsequent nursing frequency and nutrient intake. Hernández-Castellano *et al.* (2015a) demonstrated that even subtle variations in colostrum management may affect neonatal metabolism and growth performance in small ruminants.

The present findings are consistent with reports in sheep and goats where natural maternal nursing was associated with improved growth performance during the early postnatal period (Belanche *et al.*, 2012; Kenyon *et al.*, 2019). Similar observations have also been reported in calves (Godden *et al.*, 2019) and piglets (Le Dividich *et al.*, 2017), where unrestricted maternal contact and early suckling improved pre-weaning growth compared with more intensive neonatal interventions.

### **Behavioural responses**

Behavioural traits recorded during the neonatal period provide important information regarding adaptation to extra-uterine life and the establishment of maternal-offspring relationships. In the present study, maternally suckling lambs exhibited higher suckling frequency, longer suckling duration, greater walking activity, enhanced exploratory behaviour and stronger ewe–lamb bonding during the initial days postpartum. In contrast, ANC lambs spent a greater proportion of time resting.

The higher suckling frequency and duration observed in maternally suckled lambs indicate rapid establishment of nursing behaviour and stronger maternal attachment. Successful suckling during the first few hours after birth is essential not only for colostrum acquisition but also for reinforcing ewe–lamb recognition and attachment. According to Nowak and Poindron (2006), Hernández-Castellano *et al.* (2015a) and Freitas-de-Melo *et al.* (2021) maternal bonding and suckling behaviour develop simultaneously during the immediate postnatal period and strongly influence neonatal survival and welfare. The reduced suckling activity during the first few days in ANC lambs may be related to bottle-feeding immediately after birth and the additional neonatal handling associated with assisted care procedures. Although ANC lambs remained with their dams and suckled naturally thereafter, the initial

bottle feeding may have temporarily modified the normal pattern of maternal nursing behaviour. However, the absence of significant differences in suckling behaviour after day 4 indicates that ANC lambs adapted rapidly to natural nursing conditions.

Maternal suckling lambs also displayed greater locomotor and exploratory activities, suggesting enhanced neonatal vigour and environmental interaction. Similar behavioural patterns have been described in neonatal lambs and goat kids, where naturally reared offspring exhibited higher activity levels and stronger maternal attachment than animals subjected to early management interventions (Dwyer, 2008 and Belanche *et al.*, 2012).

Conversely, ANC lambs showed higher resting behaviour during the observation period. Increased resting activity in neonates may reflect reduced locomotor activity or adaptation to handling stress during the early postnatal period. Nevertheless, the gradual reduction in behavioural differences observed towards the end of the first week suggests successful adaptation of lambs under both neonatal management systems (Simeonov *et al.*, 2026).

Lower ewe–lamb bond scores noted in ANC lambs during the initial four days were likely due to a temporary disruption in maternal contact and a delay in olfactory imprinting. Maternal bonding plays a vital role in initiating nursing, regulating temperature, and fostering behavioural development in lambs. Dwyer *et al.* (2003) similarly indicated that early management interventions can temporarily hinder maternal interactions and suckling behaviour. Nevertheless, the normalization of bond scores after Day 5 suggests a behavioural resilience and a recovery of the ewe–lamb relationship over time.

Increased vocalization frequencies in MS lambs during the early days further demonstrated active maternal communication and nursing interactions. Freitas-de-Melo *et al.* (2021) noted that vocalization behaviour is closely linked to the establishment of maternal bonding and neonatal adaptation immediately following birth.

### **Hematobiochemical responses**

Haematological and biochemical parameters are widely used indicators of neonatal physiological adaptation and health status. In the present study, no significant differences were observed between the two groups at birth, indicating comparable physiological status of lambs before colostrum ingestion.

Elevated levels of Hb, PCV, albumin, globulin and total protein in MS lambs suggest improved metabolic adaptation and more effective utilization of colostrum during the critical neonatal phase. Similar enhancements

in neonatal haematological and biochemical parameters following sufficient colostrum intake have been documented in lambs (Bornez *et al.*, 2009). Globulin and total protein are well-established markers of passive transfer efficiency, and their increased levels in MS lambs affirm the superior absorption of colostrum bioactive components (Kaneko *et al.*, 2008; Hernández-Castellano *et al.*, 2014; Abuelo *et al.*, 2021).

At birth, immunoglobulin concentrations were low and similar across both groups, indicating the lack of prenatal antibody transfer via the epitheliochorial placenta in sheep. Nevertheless, significantly higher concentrations of IgG and IgM at 24 hours in MS lambs indicate a more effective passive immune transfer under natural nursing conditions. Early and unrestricted suckling likely facilitated prompt colostrum consumption and enhanced immunoglobulin absorption prior to intestinal closure. Hernandez-Castellano *et al.* (2015, 2019) similarly found increased serum IgG levels in lambs that received early maternal colostrum. Similar results have also been reported in goat kids (Belanche *et al.*, 2012), suckling calves (Godden *et al.*, 2019; Renaud *et al.*, 2018), and lambs kept with their mothers (Manrique *et al.*, 2024).

### Passive immunity

The establishment of passive immunity is a critical determinant of neonatal survival in sheep because the epitheliochorial placenta prevents prenatal transfer of immunoglobulins from ewe to foetus. Consequently, lambs depend entirely on colostrum ingestion and absorption during the first hours after birth for acquiring humoral immunity.

In the present study, serum IgG and IgM concentrations at birth were negligible and did not differ significantly between the two groups, confirming the absence of prenatal immunoglobulin transfer. However, substantial increases in serum IgG and IgM concentrations were observed at 24 h postpartum, with maternally suckled lambs exhibiting significantly higher values than ANC lambs.

The higher immunoglobulin concentrations in the MS group may be attributed to uninterrupted maternal nursing, more frequent suckling and improved efficiency of colostrum utilization during the immediate postnatal period. Hernández-Castellano *et al.* (2015a, b; Yang *et al.*, 2025b) demonstrated that early and repeated colostrum intake markedly enhances serum IgG concentrations in neonatal lambs. Likewise, Pascual-Alonso *et al.* (2020) reported that lambs remaining continuously with their dams exhibited more efficient passive transfer than lambs subjected to modified

neonatal management practices. Similar results have also been reported in goat kids (Belanche *et al.*, 2012; Yang *et al.*, 2025a), suckling calves (Godden *et al.*, 2019; Renaud *et al.*, 2018), and lambs kept with their mothers (Manrique *et al.*, 2024).

Although, ANC lambs received maternal colostrum immediately after birth through bottle feeding, the initial handling procedures and differences in early nursing behaviour may have influenced the efficiency of immunoglobulin absorption. Nevertheless, the substantial post-colostral increase in IgG and IgM concentrations observed in both groups indicates that passive immunity transfer was successfully established under both neonatal management systems.

### Conclusion

The current research revealed that neonatal nursing management had a significant impact on growth performance, behavioural adaptation, hematobiochemical status, and passive immunity in indigenous Sonadi lambs raised under intensive management conditions. Lambs that were reared through maternal suckling showed increased body weight and weekly weight gain, greater suckling activity, improved exploratory behaviour, and stronger bonding with their ewes during the early neonatal phase. Additionally, maternal suckling correlated with elevated serum levels of total protein, globulin, IgG, and IgM at 24 hours postpartum, suggesting a more effective transfer of passive immunity and physiological adaptation. Although lambs receiving assisted neonatal care were given maternal colostrum immediately after birth and remained with their mothers thereafter, variations in early management practices seemed to affect neonatal behavioural responses and colostrum utilization. Nonetheless, both neonatal management approaches facilitated successful adaptation and passive immune transfer in the lambs. In summary, continuous maternal suckling under intensive management conditions may offer benefits regarding growth, behaviour, and immune status during the neonatal phase in Sonadi lambs.

### Declaration of competing interest

The author report there no competing interest to declare.

### Funding details

This research was supported by the College of Veterinary and Animal Science, Navania through grants provided for research conducted by post-graduate students under the Master of Veterinary Science (MVSc) Scholar Research Fund (RAJUVAS, Bikaner) and by Principal investigator of Project on Sonadi sheep

improvement networking programme, CVAS, Navaia, Udaipur (RAJUVAS) running under the aegis of ICAR, New Delhi.

### Acknowledgements

The authors are thankful to the Dean, College of Veterinary and Animal Science, Navania and Principal Investigator Network project on Sheep improvement (NWPSI, Sonadi Unit) at CVAS, Navania, Rajasthan (India) for providing necessary facilities to conduct this research.

### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly to improve readability and language. After using this tool, the authors reviewed and edited the content as needed. The authors developed all scientific concepts, conclusions and interpretations. The authors take full responsibility for the content of the published article.

### References

- Abuelo, A., Havrlant P., Wood N. and Hernandez-Jover M. (2021). An investigation of dairy calf management practices, colostrum quality, failure of transfer of passive immunity and occurrence of enteropathogenesis among Australian dairy farms. *Preventive Vet. Med.*, **186**: 105227. <https://doi.org/10.1016/j.prevetmed.2020.105227>.
- Alves, A.C., Alves N.G., Ascari I.J., Junqueira F.B., Coutinho A.S., Lima R.R., Pérez J.R.O., De Paula S.O. and Furusho-Garcia I.F. (2015). Colostrum composition of Santa Inês sheep and passive transfer of immunity to lambs. *J. Dairy Sci.*, **98**, 3706-3716. <https://doi.org/10.3168/jds.2014-8741>.
- Belanche, A., Doreau M., Edwards J.E., Moorby J.M., Pinloche E. and Newbold C.J. (2012). Shifts in the rumen microbiota due to the type of carbohydrate and level of protein ingested by dairy cattle are associated with changes in rumen fermentation. *J. Nutr.*, **142**, 1684-1692. <https://doi.org/10.3945/jn.112.159574>.
- Bórnez, R., Linares M.B. and Vergara H. (2009). Haematological, hormonal and biochemical blood parameters in lamb: Effect of age and blood sampling time. *Livestock Science*, **121**, 200-206. <https://doi.org/10.1016/j.livsci.2008.06.009>.
- Conneely, M., Berry D.P., Sayers R., Murphy J.P., Lorenz I., Doherty M.L. and Kennedy E. (2013). Factors associated with the concentration of immunoglobulin G in the colostrum of dairy cows. *Animal*, **7**, 1824-1832. <https://doi.org/10.1017/S1751731113001444>.
- Costa, A.P. da, Leigh A.E., Man M.S. and Kendrick K.M. (2004). Face pictures reduce behavioural, autonomic, endocrine and neural indices of stress and fear in sheep. *Proceedings of the Royal Society B*, **271**, 2077-2084. <https://doi.org/10.1098/rspb.2004.2831>.
- Devillers, N., Farmer C., Le Dividich J. and Prunier A. (2007). Variability of colostrum yield and colostrum intake in pigs. *Animal*, **1**, 1033-1041. <https://doi.org/10.1017/S175173110700016X>.
- Dwyer, C.M. (2008). The welfare of the neonatal lamb. *Small Ruminant Res.*, **76**, 31-41. <https://doi.org/10.1016/j.smallrumres.2007.12.011>.
- Dwyer, C.M., Conington J., Corbiere F., Holmy I.H., Muri K., Nowak R., Rooke J., Vipond J. and Gautier J.M. (2016). Improving neonatal survival in small ruminants: Science into practice. *Animal*, **10**, 449-459. <https://doi.org/10.1017/S1751731115001974>.
- FAO (2012). *Phenotypic Characterization of Animal Genetic Resources*. FAO Animal Production and Health Guidelines No. 11. Food and Agriculture Organization of the United Nations, Rome.
- Freitas-de-Melo, A. and Orihuela A. (2022). What do we know and need to know about weaning in sheep? An overview of weaning practices, stress and welfare. *Front. Anim. Sci.*, **3**, 823188. <https://doi.org/10.3389/fanim.2022.823188>.
- Godden, S.M., Lombard J.E. and Woolums A.R. (2019). Colostrum management for dairy calves. *Vet. Clin. North Amer.: Food Anim. Pract.*, **35**, 535-556. <https://doi.org/10.1016/j.cvfa.2019.07.005>.
- Government of India (2019). *20th Livestock Census*. Department of Animal Husbandry and Dairying, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, New Delhi.
- Hernández-Castellano, L.E., Almeida A.M., Ventosa M., Coelho A.V., Castro N. and Argüello A. (2014). The effect of colostrum intake on plasma proteome profile in newborn lambs: Low abundance proteins. *BMC Vet. Res.*, **10**, 85. <https://doi.org/10.1186/1746-6148-10-85>.
- Hernández-Castellano, L.E., Morales-Delanuez A., Sánchez-Macías D., Moreno-Indias I., Torres A., Capote J., Argüello A. and Castro N. (2015a). The effect of colostrum source and timing of first feeding on body weight and immune status of artificially reared newborn lambs. *J. Dairy Sci.*, **98**, 204-210. <https://doi.org/10.3168/jds.2014-8350>.
- Hernández-Castellano, L.E., Suárez-Trujillo A., Martell-Jaizme D., Cugno G., Argüello A. and Castro N. (2015b). The effect of colostrum period management on body weight and immune system in lambs from birth to weaning. *Animal*, **9**, 1672-1679. <https://doi.org/10.1017/S175173111500110X>.
- Johnsen, J.F., Zipp K.A., Kälber T., De Passillé A.M., Knierim U., Barth K. and Mejdell C.M. (2015). Is rearing calves with the dam a feasible option for dairy farms? Current and future research. *Appl. Anim. Behav. Sci.*, **181**, 1-11. <https://doi.org/10.1016/j.applanim.2015.11.011>.
- Kaneko, J.J., Harvey J.W. and Bruss M.L. (2008). *Clinical Biochemistry of Domestic Animals*. 6th Ed. Academic Press, San Diego.
- Kumar, A., Misra S.S., Chopra A., Gowane G.R., Arora A.L. and Prince L.L.L. (2021). Sheep breeding in north-western arid and semi-arid regions of India: An overview. *Indian J. Small Rumin.*, **27**, 1-10. <https://doi.org/10.5958/0973->

9718.2021.00013.1.

- Le Dividich, J., Charneca R. and Thomas F. (2017). Relationship between birth order, birth weight, colostrum intake, acquisition of passive immunity and pre-weaning mortality of piglets. *Spanish J. Agricult. Res.*, **15**, e0603. <https://doi.org/10.5424/sjar/2017152-9921>.
- Martin, P. and Bateson P. (2015). *Measuring Behaviour: An Introductory Guide*. 3rd Ed. Cambridge University Press, Cambridge.
- Mellor, D.J. and Stafford K.J. (2004). Animal welfare implications of neonatal mortality and morbidity in farm animals. *Vet. J.*, **168**, 118-133. <https://doi.org/10.1016/j.tvjl.2003.08.004>.
- Napolitano, F., De Rosa G. and Sevi A. (2008). Welfare implications of artificial rearing and early weaning in sheep. *Appl. Anim. Behaviour Sci.*, **110**, 58-72. <https://doi.org/10.1016/j.applanim.2007.03.020>.
- Nowak, R. and Poindron P. (2006). From birth to colostrum: Early steps leading to lamb survival. *Reprod. Nutr. Develop.*, **46**, 431-446. <https://doi.org/10.1051/rnd:2006023>.
- Poindron, P., Nowak R., Lévy F., Porter R.H. and Schaal B. (1993). Development of exclusive mother-young bonding in sheep and goats. *Oxford Rev. Reprod. Biol.*, **15**, 311-364.
- Quesnel, H., Farmer C. and Devillers N. (2012). Colostrum intake: Influence on piglet performance and factors of variation. *Livestock Sci.*, **146**, 105-114. <https://doi.org/10.1016/j.livsci.2012.03.010>.
- R Core Team (2024). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- Sharma, P.C., Meena R. and Kumar S. (2019). Genetic and phenotypic parameters for growth traits of Sonadi sheep. *Indian J. Anim. Sci.*, **89**, 1020-1023. <https://doi.org/10.56093/ijans.v89i9.93838>.
- Sveinbjornsson, J., Eythórsdóttir E. and Örnólfsson E.K. (2021). Factors affecting birth weight and pre-weaning growth rate of lambs from the Icelandic sheep breed. *Small Rumin. Res.*, **200**, 106420. <https://doi.org/10.1016/j.smallrumres.2021.106420>.
- Vasseur, E., Borderas F., Cue R.I., Lefebvre D., Pellerin D., Rushen J., Wade K.M. and De Passillé A.M. (2010). A survey of dairy calf management practices in Canada that affect animal welfare. *J. Dairy Sci.*, **93**, 1307-1315. <https://doi.org/10.3168/jds.2009-2429>.
- Yang, C., Du M., Ahmad A.A., Cheng Y. and Gebeyew K. (2025a). Passive immunity establishment through colostrum IgG absorption in neonatal ruminants: Foundation for efficient ruminant production. *Animals*, **15**, 3093. <https://doi.org/10.3390/ani15213093>.
- Yang, H., Wang Y. and Li X. (2025b). Advances in neonatal immunity and colostrum-mediated passive transfer in small ruminants. *Front. Immunol.*, **16**, 1483920. <https://doi.org/10.3389/fimmu.2025.1483920>.