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Review Article

Neonatal physiology of Ghungroo pigs: A review

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Abstract

Ghungroo pigs are notable local genetic resource for minimal input production systems in the eastern Sub-Himalayan region of India's West Bengal state. The pre-weaning mortality rate of Ghungroo piglets was lower compared to non-descript native, purebred and crossbred pigs, and the present review aimed to find out some salient features of neonatal Ghungroo piglets for their lower mortality rates. Ghungroo piglets are able to maintain their body temperature upto 2 months without any artificial thermoregulatory support. The hemoglobin concentration of neonatal Ghungroo piglets was higher compared to crossbred piglets. Ghungroo piglets were able to maintain steady blood glucose and total protein concentration till the weaning without affecting liver functions. Increased plasma cortisol soon after weaning provides additional metabolic support to maintain steady glucose level. Ghungroo piglets maintain the total antioxidant status from 4th to 7th week after birth with higher lymphocyte proliferation response.

Keywords: Endocrine, Ghungroo, Immunity, Physiology, Piglets

Highlights

- Ghungroo piglets are able to maintain their body temperature up to 2 months without any artificial thermoregulatory support.
- The hemoglobin concentration of neonatal Ghungroo piglets was higher compared to crossbred piglets.
- Ghngroo piglets are able to maintain steady blood glucose and total protein concentration till weaning without affecting liver functions.
- Increased plasma cortisol soon after weaning provides additional metabolic support to maintain steady glucose level.
- Ghungroo piglets maintain the total antioxidant status from 4th to 7th week after birth with higher lymphocyte proliferation response

INTRODUCTION

The morbidity and mortality of neonatal piglets are of great concern for the pig industry. Approximately 15–20% mortality of newborn piglets was reported worldwide at the time of farrowing and early lactation despite of good husbandry system (Baxter and Edwards, 2018). The selection pressure to create highly prolific sow line was reported to be the main predisposing factor for neonatal death due to stillborn piglets with lack of energy reserve, impaired thermoregulation and crushing by the sow (Edwards and Baxter, 2015; Edwards *et al*., 2019). Therefore, the neonatal period is considered as one of the critical period during which all the adaptation processes related to transition from intrauterine to extrauterine life is going to happen (Zavalishina, 2018[a,b]). The high metabolic demands during the accelerated growth phase can only be met with adequate energy reserves. Therefore, the piglets with poor energy reserve are most vulnerable to mortality during birth and the early post-natal period (Farmer and Edwards, 2022). Ghungroo is a native pig breed of eastern Sub-Himalayan region of the state of West Bengal, India (Pan *et al*., 2005) and is a valuable local genetic resource suitable under a low input production system (Boro *et al*., 2021). High fecundity, body weight gain, feed conversion ability and early maturity are important economic traits of Ghungroo pigs (Boro *et al*., 2021). Ghungroo pigs attain puberty at 6.48±0.24 to 7.8±0.41 months and become sexually mature at 9.39±0.32 to 6.255±0.144 months (Sahoo, 2012; Gokuldas *et al*., 2015; Boro *et al*., 2021). According to Boro *et al*. (2021), the age at first farrowing and farrowing interval of Ghungroo pigs were 14.06±0.25 months and 6.93±0.24 months, respectively. He also documented the gestation period of Ghungroo pigs was 113.22±0.49 days, and birth weight and litter size were 0.97±0.01 kg and 8.22±0.46, respectively. A five year study on the Ghungroo pigs under organized farming system revealed

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5.17% mortality rate (Mondal *et al*., 2023) which was much lower than non-descript native, purebred and crossbred pigs (Kumaresan *et al*., 2007; Boro *et al*., 2021). The highest mortality was recorded during pre-weaning period due to pneumonia, crushing, hypoglycemia, debility, inanition, and enteritis (Mondal *et al*., 2023). The present review encompasses physio-biochemical, endocrine, antioxidant status and immunity of neonatal Ghungroo piglets which can be a very useful tool to monitor neonatal health status and accordingly therapeutic and managemental interventions can be made.

Physiological parameters

Physiological responses are the important parameters to evaluate adaptation of an animal to a given geographical location (Ribeiro *et al*., 2015). Studies have reported that physiological parameters directly influenced pre-weaning mortality in piglets and hence helped to predict early loss (Trujillo-Ortega *et al*., 2007). The newborn piglets are vulnerable to hypothermia due to lack of body insulation and brown fat (Berthon *et al*., 1996), whereas small number of sweat glands, thick layer of subcutaneous fat and low body surface to body mass ratio in adult pigs make more susceptible to heat stress (Bracke, 2011). In piglets, the body temperature is reported to decrease by 2-4°C at birth which gradually normalizes to 39°C within 24-48 hours (Lossec *et al*., 1998). Neonatal hyperthermia in piglets was reported to be associated with blood glucose, glucagon, adrenaline, noradrenaline and thyroid hormones, which were increased as a compensatory mechanism to cope up the hypothermia (Macari *et al*., 1986; Lossec *et al*., 1998). But Ghungroo piglets are able to maintain their body temperature upto 2 months (Nath *et al*., 2016; Lodh *et al*., 2022) without any artificial thermoregulatory support; however, reduction of mortality by 10.6% was reported after artificial heat supplementation (Nath *et al*., 2016). In a related study, Das, (2022) reported a progressive decrease in body temperature from 4th to 10th week in Ghungroo piglets. The pulse rate of Ghungroo piglets was reported to be 65.75±1.99/min at 1st week, 57.00±1.99/min at 3rd week, 68.73±1.99/min at 6th week, 64.45±1.99/min at 9th week and 68.51±1.99/min at 12th week (Lodh *et al*., 2022). A significant increase in the pulse rate of Ghungroo piglets was reported during weaning and continued up to 10th week (Das, 2022). Studies have reported that pneumonia or respiratory infections contribute to 14.3% death in piglets reared in organized farm (Mondal *et al*., 2023). A decreasing trend in respiration rate of Ghungroo piglets was observed from 1st (58.25±1.59) to 12th week (47.94±1.59) (Lodh *et al*., 2022). But, much lower respiration rates (84.62±1.47) were reported by Das (2022) in Ghungroo piglets compared to the study of Lodh *et al*. (2022).

Hematological parameters

The hemoglobin concentration (g/dL) of Ghungroo pigs were 10.54±0.48 to 14.84±0.46 from 0 to 90 days (Hazorika *et al*., 2017; Das, 2022; Lodh *et al*., 2022), which was higher than the reported values of crossbred piglets (Thorn, 2010) and comparable with the local Zovawk pigs of Mizoram (Mayengbam *et al*., 2014) and Mali piglets (Paul *et al*., 2020). The mean erythrocyte counts (X 10^6/µL) of Ghungroo piglets were found to be 3.96±0.25 at 1st week which increased significantly up to 18th week (7.12±0.25) (Das, 2022; Lodh *et al*., 2022). The packed cell volume (%) was higher during the first week of life and gradually declined up to 18th week. Lodh *et al*. (2022) documented total leukocyte counts (X 10^3/µL) of Ghungroo piglets were 10.8±0.31 (1st week) to 12.2±0.31 (12th week), which were comparable with crossbred piglets (Thorn, 2010). Among the erythrocyte indices, mean corpuscular volume was higher during 1st week and gradually declined upto 18th week (Das, 2022; Lodh *et al*., 2022). In Ghungroo piglets, higher total leukocyte count (TLC) was reported immediately after weaning but remained stable till 9th week of age (Lodh *et al*., 2022). The lymphocytes and monocytes were also higher around the weaning period (Lodh *et al*., 2022).

Blood biochemical profile

Blood glucose concentration in newborn piglets was one of the main determining factors for the survival of newborn piglets. Piglets with higher blood glucose concentration (45-162 mg/dL) had a significantly lower mortality rate compared to the piglets with low (24 - 30 mg/dL) blood glucose concentration (Panzardi *et al*., 2013). Ghungroo piglets were able to maintain a steady blood glucose concentration till the weaning. The blood glucose concentration of Ghungroo piglets was reported to be 96.9±6.87 and 111.1± 6.87 mg/dL during 1st and 3rd weeks after birth. But a declining trend was reported from 6th week onwards due to weaning (Lodh *et al*., 2022). The said values were 71.5±6.87, 64.8±6.87 and 52.7±6.87, 68.10±2.27 and 75.13±2.27, respectively for 6th, 9th 12th, 14th and 18th week (Das, 2022; Lodh *et al*., 2022). Neonatal hypogammaglobulinemia is common in piglets due to poor transfer of maternal immunoglobulins in utero which is compensated by colostrum feeding within 24 to 36 hours after birth (Butler, 1999). But, the total protein concentration of Ghungroo piglets was consistent during 1st to 12th weeks after and ranged from 9.17±0.47 g/dL to 7.91±0.47 g/dL (Das, 2022; Lodh *et al*., 2022), but a significant drops in globulin concentration and higher albumin:globulin ratio were reported after weaning (Lodh

et al., 2022). Plasma cholesterol concentration of Ghungroo was highest on the 1st week after birth and then declined significantly till 9th week of post-natal life (Lodh *et al*., 2022). Much lower cholesterol level was reported from 10th week onwards till 18th week of post-natal period (Das, 2022). The liver enzymes, namely alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were reported to remain unchanged from birth to 18th week of age in Ghungroo piglets (Das, 2022). In a related study, Nath *et al*. (2016) reported lower AST and ALT levels in Ghungroo piglets exposed to the artificial heat source.

Endocrine parameters

The cortisol concentration was reported to follow a declining trend with the advancement of age in piglets due to increased binding of cortisol with corticosteroid-binding globulin (CBG) (Kattesh *et al*., 1990; Grant *et al*., 2017). Weaning stress increased plasma cortisol levels with increased expression of StAR and steroidogenic enzyme mRNA levels to contribute higher plasma cortisol (Li *et al*., 2016) and remained elevated till 7-day post-weaning period (Moeser *et al*., 2007). The concentration of plasma cortisol in Ghungroo piglets was studied from 1st week to 12th week, and the values were 2.45, 2.68, 2.85, 3.21 and 3.56 mmol/L during 1st, 3rd, 6th, 9th and 12th weeks of age (Lodh *et al*., 2022). In a related study, Das (2022) found plasma cortisol concentrations as 43.17, 46.91, 42.68, 38.40 and 35.05 ng/mL during 4th, 7th, 10th 14th and 18th week. The age related changes in the plasma and salivary cortisol level were reported in pigs, and the pattern showed an initial increase followed by a declining trend with the advancement of age (Kirkwood *et al*., 1987; Ruis *et al*., 1997). de Jong (2000) studied about cortisol concentration in relation to age in crossbred pigs and found that the cortisol concentration increased with the advancement of age upto 15th weeks and then gradually declined to the baseline at 22nd week of age. A decrease in the basal cortisol concentration was reported between 12th and 24th week of age in crossbred pigs (Evans *et al*., 1988; Ruis *et al*., 1997). In a related study, Heimbürge *et al*. (2020) reported decreased concentrations of hair cortisol in crossbred piglets from 10th to 27th week of age. The decreased cortisol level at this age may be due to increased binding of cortisol with corticosteroid-binding globulin (CBG) which gradually increases after 6th week of age (Kattesh *et al*., 1990; Grant *et al*., 2017). Additional supplementation of heat to newborn Ghungroo piglets had no effect on plasma cortisol and thyroid hormone level (Nath *et al*., 2016). The thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3) play significant roles in metabolic activity, growth and production performance in many species including pigs (Todini *et al*., 2006; Lkhagvadorj, 2010; Medrano and He, 2016). The growth promoting effects of T3 and T4 include energy homeostasis, skeletal development (Bianco and McAninch, 2013; Salvatore *et al*., 2014), increase in feed conversion efficiency and protein accumulation in muscles (Neubert *et al*., 1999). The highest concentration of T_3 and T_4 were reported in newborn piglets, which followed a declining trend with the advancement of age (Paulíková *et al*., 2011). T3 (ng/mL) concentration in Ghungroo piglets was reported to be 9.17, 7.07, 7.03, 11.16 and 6.09 ng/mL during 1st, 3rd, 6th, 9th and 12th weeks of age (Lodh *et al*., 2022), but in a related study, Das (2022) found less value of plasma T_3 in Ghungroo piglets from 1.79 and 1.14 ng/mL during 4th and 18th week of age. The thyroxine concentration from birth to 9th week of age were 44.5, 48.2, 38.5, 39.7 and 29.6 µg/dL in 1st, 3rd, 6th, 9th and 12th weeks of age (Lodh *et al*., 2022).

Antioxidant status

Excessive free radicals are accumulated at the time of birth in piglets due to poor activity of antioxidant enzymes like glutathione peroxidase (GSH-Px) and superoxide dismutase (SOD) (Hao *et al*., 2021). The activity of GSH-Px and SOD increased significantly on day 7 after birth (Hao *et al*., 2021). It was further confirmed by the study of Yin *et al*. (2013), which reported higher blood lipid oxidation product malondialdehyde (MDA) as a measure of oxidative stress at birth which decreased significantly on day 7 after birth in piglets. Weaning also induces oxidative stress in pigs (Hao *et al*., 2021). A significant increase in the blood MDA concentration and protein hydroxyl (marker of protein oxidative damage) were reported immediately after weaning in piglets (Luo *et al*., 2016). Studies have confirmed that activity of GSH-Px and SOD were decreased at weaning (Shin *et al*., 2018) with an increased level of oxygen free radical hydrogen peroxide (H_2O_2) in liver (Luo *et al*., 2016). But, in Ghungroo piglets, the total antioxidant status remained higher from 4th to 7th weeks after birth and then gradually declined up to 18th weeks (Das, 2022). Supplementation of dietary turmeric and lemon essential oil significantly improved total antioxidant status after 10th weeks of age (Das, 2022).

Immune status

The newborn piglets acquire sufficient immune competence in terms of innate immunity, but the adaptive immune response is poorly developed as the placenta does not allow the transfer of maternal antibodies to fetus (Sinkora and Butler, 2009). Apart from the nutritional support, colostrum provides maternal antibodies, immune cells and antimicrobial proteins that induce immune tolerance. The antigenic stimuli from environment and commensal microbial flora

activate T and B lymphocytes along with mucosal immune cells (Sinkora and Butler, 2009; Azizi *et al*., 2022). But limited literatures were available about the immune status of Ghungroo pigs. In our laboratory, we evaluated *in vitro* phagocytic activity (PA) of neutrophils and mitogen induced *in vitro* lymphocyte proliferation response (LPR) from birth to 18th weeks in Ghungroo piglets, and the highest phagocytic activity was found around 9th weeks, whereas, LPR was highest on 3rd weeks after birth (Das, 2022; Lodh *et al*., 2022).

Conclusions

The Ghungroo piglets have some unique physio-biochemical, endocrine and immune features that make them thrive well under low input production system. Higher thermoregulatory response, steady blood glucose and protein level, and endocrine and metabolic integration facilitate lower pre-weaning mortality rate in Ghungroo piglets.

Conflict of Interest: The authors don't have any conflict of interest.

Author's contributions: JM, PKD: Conceived the idea; SL, AKD, TS, RH: Share their work related to the topic; JM: Drafted the manuscript; PRG, KD, DB: Corrected the manuscript. All the authors have seen and agreed with the final manuscript.

REFERENCES

Azizi AFN, Uemura R, Omori M, Sueyoshi M and Yasuda M, 2022. Effects of probiotics on growth and immunity of piglets. Animals,12(14): 1786, doi: 10.3390/ani12141786

Baxter EM and Edwards SA, 2018. Piglet mortality and morbidity: inevitable or unacceptable? (Spinka M, Eds), Advances in Pig Welfare, Elsevier, pp 73-100, doi: 10.1016/B978-0-08-101012-9.00003-4

Berthon D, Herpin P, Bertin R, De Marco F and Le Dividich J, 1996. Metabolic changes associated with sustained 48-hr shivering thermogenesis in the newborn pig. Comp Biochem Physiol B Biochem Mol Biol, 114(4): 327-335, doi: 10.1016/0305-0491(96)00044-2

Bianco AC and McAninch EA, 2013. The role of thyroid hormone and brown adipose tissue in energy homoeostasis. Lancet Diabetes Endocrinol, 1(3): 250-258, doi: 10.1016/S2213-8587(13)70069-X

Boro P, Bharali, D, Sarma M, Sonowal M, Saharia J *et al*., 2021. Performances of Ghungroo pigs reared under farm condition. J Entomol Zool Stud, 9(1): 2265-2267

Bracke MBM, 2011. Review of wallowing in pigs: description of the behaviour and its motivational basis. Appl Anim Behav, 132(1-2): 1-13, doi: 10.1016/j.applanim.2011.01.002

Butler JE, 1999. Immunoglobulins and immunocytes in animal milks. Mucosal Immunology. (Ogra PL, eds) 2nd edn. Academic Press, New York, pp 1531-1554

Das AK, 2022. Effects of dietary turmeric and lemon essential oil on weaning and post-weaning physiological performances of Ghoongroo piglets. M. V. Sc thesis submitted to the West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India

de Jong I, 2000. Chronic stress parameters in pigs: Indicators of animal welfare? [Thesis fully internal (DIV), University of Groningen]. University of Groningen. Available at: https://chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://research.rug.nl/files/14525520/c1.pdf

Edwards SA and Baxter EM, 2015. Piglet mortality: causes and prevention. (Farmer C, Eds), The gestating and lactating sow. Wageningen Academic Publishers, Wageningen, Netherlands, pp 253-278. Available at: https://pure.sruc.ac.uk/en/publications/piglet-mortality-causes-and-prevention

Edwards SA, Matheson SM and Baxter EM, 2019. Genetic influences on intrauterine growth retardation of piglet and management interventions for low birth weight piglets. (Agricola Española Eds), Nutrition of hyper prolific sows. Novus International Inc, Madrid, Spain, pp 207-235

Evans FD, Christopherson RJ and Aherne FX, 1988. Development of the circadian rhythm of cortisol in the gilt from weaning until puberty. Can J Anim Sci, 68: 1105-1111, doi: 10.4141/cjas88-126

Farmer C and Edwards SA, 2022. Review: Improving the performance of neonatal piglets. Animals, 16(Suppl 2): 100350, doi: 10.1016/j.animal.2021.100350

Gokuldas PP, Tamuli, MK, Mohan NH, Barman K and Sahoo NR, 2015. A comparative analysis of reproductive performance of different pig breeds under intensive management systems in sub-tropical climate. Ind J Anim Sci, 85(9): 1042-1045

Grant K, Worlein J, Meyer J, Novak M, Kroeker R *et al*., 2017. A longitudinal study of hair cortisol concentrations in *Macaca nemestrina* mothers and infants. Am J Primatol, 79(2): 1-9, doi: 10.1002/ajp.22591

Hao Y, Xing M and Gu X, 2021. Research progress on oxidative stress and its nutritional regulation strategies in pigs. Animals, 11(5): 1384, doi: 10.3390/ani11051384

Hazorika M, Sarma S, Kalita DJ, Barua KK and Tamuli MK, 2017. Influence of dietary energy and protein levels on growth performance and some blood biochemical indices of growing indigenous (Ghungroo) pigs. Int J Chem Stud, 5(2): 390-395

Heimbürge S, Kanitz E, Tuchscherer A and Otten W, 2020. Within a hair's breadth – factors influencing hair cortisol levels in pigs and cattle. Gen Comp Endocrinol, 288: 113359, doi: 10.1016/j.ygcen.2019.113359

Kattesh HG, Charles SF, Baumbach GA and Gillespie BE, 1990. Plasma cortisol distribution in the pig from birth to six weeks of age. Biol Neonate, 58(4): 220-226, doi: 10.1159/000243271

Kirkwood RN, Evans FD and Aherne FX, 1987. Influence of age, weight and growth rate on basal LH, growth hormone and cortisol, and estrogen-induced LH release in prepubertal gilts. Can J Anim Sci, 67: 1001-1010, doi: 10.4141/cjas87-105

Kumaresan A, Bujarbaruah KM, Pathak KA, Chhetria B, Das SK *et al*., 2007. Performance of pigs reared under traditional

tribal low input production system and chemical composition of non-conventional tropical plants used as pig feed. Livest Sci, 107(2): 294-298, doi: 10.1016/j.livsci.2006.12.007

Li LA, Yang JJ, Li Y, Lv L, Xie JJ *et al*., 2016. Effect of weaning age on cortisol release in piglets. Genet Mol Res, 15(2): PMID: 27173313, doi: 10.4238/gmr.15027693

Lkhagvadorj S, 2010. Effects of selection for low residual feed intake and feed restriction on gene expression profiles and thyroid axis in pigs. PhD thesis, Iowa State University, Ames, IA, USA, doi: 10.31274/etd-180810-505

Lodh S, Das PK, Mukherjee J, Naskar S, Banerjee D *et al*., 2022. Effect of dietary oregano essential oil and milk replacer on physiological status and immunological responses of pre- and post-weaned Ghoongroo piglets. Anim Biotechnol, doi: 10.1080/10495398.2022.2118131

Lossec G, Herpin P and Le Dividich J, 1998. Thermoregulatory responses of the newborn pig during experimentally induced hypothermia and rewarming. Exp Physiol, 83(5): 667-678, doi: 10.1113/expphysiol.1998.sp004148

Luo Z, Zhu W, Guo Q, Luo W, Zhang J *et al*., 2016. Weaning induced hepatic oxidative stress, apoptosis, and aminotransferases through MAPK signaling pathways in piglets. Oxid Med Cell Longev, 2016: 4768541, doi: 10.1155/2016/4768541

Macari M, Zuim SM, Secato ER and Guerreiro JR, 1986. Effect of ambient temperature and thyroid hormone on food intake by pigs. Physiol Behav, 36(6): 1035-1039, doi: 10.1016/0031-9384(86)90476-2

Mayengbam P, Tolenkhomba TC and Ali MA, 2014. Haematological profile of Zovawk- An indigenous pig of Mizoram. Vet World, 7(7): 505-508, doi: 10.14202/vetworld.2014.505-508

Medrano RF and He JH, 2016. Advances in thyroid hormones function relate to animal nutrition. Ann Thyroid Res, 2(1): 45-52

Moeser AJ, Klok CV, Ryan KA, Wooten JG, Little D *et al*., 2007. Stress signaling pathways activated by weaning mediate intestinal dysfunction in the pig. Am J Physiol Gastrointest Liver Physiol, 292(1): G173-G181, doi 10.1152/ajpgi.00197.2006

Mondal D, Naskar S and Biswas TK, 2023. Epizootics associated in Ghoongroo pig mortality in an organized farm under hot and humid climatic condition in West Bengal, India. Acta Sci Vet Sci, 5(3): 47-52, doi: 10.31080/ASVS.2023.05.0616

Nath H, Hazorika M, Rajkhowa D, Datta M and Haldar A, 2016. Effect of supplemental heat on mortality rate, growth performance, and blood biochemical profiles of Ghungroo piglets in Indian sub-tropical climate. Vet World, 9(4): 396-402, doi: 10.14202/vetworld.2016.396-402

Neubert E, Scholze C, Kratzsch J and Gürtler H, 1999. Plasma levels of catecholamine and lipolysis during starvation in growing pigs. J Vet Med Series A, 46(4): 247-253, doi: 10.1046/j.1439-0442.1999.00213.x

Pan S, Misra SK and Kundu MS, 2005. Ghoongroo pig: A new found animal genetic resource of Sub-Himalayan West Bengal, India. Anim Genet Resour Inf, 37: 91-96, doi: 10.1017/S1014233900002005

Panzardi A, Bernardi ML, Mellagi AP, Bierhals T, Bortolozzo FP *et al*., 2013. Newborn piglet traits associated with survival and growth performance until weaning. Prev Vet Med, 110(2): 206-213, doi: 10.1016/j.prevetmed.2012.11.016

Paul A, Das S, De A, Debbarma S, Roy J *et al*., 2020. Physical and reproductive features of Mali: An indigenous pig breed of Tripura with special emphasis to impact of weaning on haemato-biochemical parameters. J Entomol Zool Stud, 8(5): 1531-1536

Paulíková I, Seidel H, Nagy O, Tóthová C and Kovác G, 2011.Concentrations of thyroid hormones in various age categories of ruminants and swine. Acta Vet (Beograd), 61(5-6): 489-503, doi: 10.2298/AVB1106489P

Ribeiro NL, Pimenta Filho EC, De Arandas JKG, Ribeiro MN, Saraiva EP *et al*., 2015. Multivariate characterization of the adaptive profile in Brazilian and Italian goat population. Small Rumin Res, 123(2-3): 232-237, doi: 10.1016/j.smallrumres.2014.12.010

Ruis MAW, Te Brake JH, Engel B, Ekkel ED, Buist WG *et al*., 1997. The circadian rhythm of salivary cortisol in growing pigs: effects of age, gender and stress. Physiol Behav, 62(3): 623-630, doi: 10.1016/s0031-9384(97)00177-7

Sahoo NR, 2012. A monograph on Ghungroo pig. A new promise in Indian piggery. ICAR-NRC pig, Rani, Guwahati, India

Salvatore D, Simonides WS, Dentice M, Zavacki AM and Larsen PR, 2013. Thyroid hormones and skeletal muscle- new insights and potential implications. Nat Rev Endocrinol, 10(4): 206-214, doi: 10.1038/nrendo.2013.238

Shin KT, Guo J, Niu YJ and Cui XS, 2018. The toxic effect of aflatoxin B1 on early porcine embryonic development. Theriogenology, 118: 157-163, doi: 10.1016/j.theriogenology.2018.06.002

Sinkora M and Butler JE, 2009. The ontogeny of the porcine immune system. Dev Comp Immunol, 33(3): 273-283, doi: 10.1016/j.dci.2008.07.011

Thorn C, 2010. Hematology of the pig. (Feldman BV, Zinkl JG and Jain NC, Eds). Schalm's Veterinary Hematology. 6th edn, Lippincott Williams & Wilkins, Philadelphia, pp 843 -850

Todini L, Delgadillo JA, Debenedetti A and Chemineau P, 2006. Plasma total T3 and T4 concentrations in bucks as affected by photoperiod. Small Rumin Res, 65(1-2): 8-13, doi: 10.1016/J.SMALLRUMRES.2005.05.034

Trujillo-Ortega ME, Mota-Rojas D, Olmos-Hernández A, Alonso-Spilsbury M, González M *et al*., 2007. A study of piglets born by spontaneous parturition under uncontrolled conditions: could this be a naturalistic model for the study of intra partum asphyxia? Acta Biomed, 78(1): 29-35

Yin J, Ren W, Liu G, Duan J, Yang G *et al*., 2013. Birth oxidative stress and the development of an antioxidant system in newborn piglets. Free Radic Res, 47(12): 1027-1035, doi: 10.3109/10715762.2013.848277

Zavalishina SY, 2018[a]. Functioning of platelets in milk and vegetable nutrition calves. Res J Pharm Biol Chem Sci, 9(5): 943-949

Zavalishina SY, 2018[b]. Physiology of vascular hemostasis in newborn calves. Res J Pharm Biol Chem Sci, 9(5): 1037-1044

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