Paternally and maternally imprinted gene perturbed expression in parthenogenetic diploid embryos in *Capra hircus*

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**ABSTRACT**

The present research work was undertaken to compare the expression of paternally imprinted (P57KIP2, Grb10 and Xist) and maternally imprinted gene (Dlk1) among diploid parthenogenetic (DIP), female sexed *in vivo* and female sexed *in vitro* produced embryonic cell colony. The good quality caprine oocytes were matured in presence of cytochalasin B (CCB) and activated by ethanol (7%) for 5 min followed by incubation with 2 mM 6-dimethyl amino purine (DMAP) for 4 h for DIP embryos production. *In vivo* embryo was collected by surgical method from 10 super ovulated goats using Pluset®. *In vitro* embryos were produced by maturation of good quality oocyte followed by fertilization with superior male germplasm from the institute flock. Embryonic cell colony were developed from 8 to 16 and morula stage DIP, IVF and *in vivo* derived embryos. These colonies were used for studying the paternal and maternal imprinted genes expression. Karyotyping and sexing of embryonic cell colony was done to get only female sexed colony for this purpose. Paternally imprinted genes (P57KIP2, Grb10 and Xist) showed more expression in DIP compared to *in vivo* and IVF derived embryonic cell colony. The expression of maternally imprinted genes (Dlk1) was low in DIP compared to *in vivo* and IVF derived embryonic cell colony. The present study demonstrated that the expression profile of both paternal and maternally imprinted genes were perturbed, which may be responsible for developmental failure of parthenogenetic embryos to full term following parthenogenetic embryo transfer in goat.

**Key words**: *Capra hircus*, Diploid parthenogenetic embryos, Dlk1, Grb10, P57KIP2, Parthenogenesis, Xist

Parthenogenesis occurs as a natural process in the life history of many invertebrates and in sexually reproduced animals, the egg will be activated by artificial methods without fertilization called artificial or induced parthenogenesis. The stimulus for this may be physical, temperature, chemical, electrical etc. Preimplantation embryo development is characterized by the three distinct morphological steps, viz. compaction, cavitation and blastocoel expansion which require well-orchestrated expression of genes derived from the maternal and/or embryonic genome. *In vitro* produced embryos gene expression starts at the 2- to 4-cell stage. After fertilization, the early embryonic development is dependent on maternal mRNA that was transcribed during oocyte growth. It is only after a few cleavage divisions that the embryonic genome is activated and the embryo takes control of its own destiny.

Expression of development related genes is essential for survival of an embryo. Normal mammalian development requires both maternal (H-19, P57KIP2, Igf2r, Grb10, Gnas, Mash/Hash, Xist etc.) and paternal (Igf2, Peg1, Peg3, Dlk1, Mest, Ndn, Nnat, Sgce etc.) genes contribution to the genome for complete gene expression (Barton et al. 1984). Further, the expression of Desmocolin Type I, II, III, Desmogelin 1, Plakophilin, Connexin 43, Hsp70.1, Oct4, Nanog, Glut-1, Glut-5, Igf-1r, E-cad, Stat3, MnSOD, DNMT1, Bax, Bal2, Fgf4, Chop 10, G6pd, Aquaporins 1,3,6,7,9 etc., genes is also required for normal early embryo development. Parthenogenetic embryo fails to develop to term and exhibit phenotypic abnormalities due either the lack of expression or to overexpression of several of these developmental related genes (Kaufman et al. 1977, Barton et al. 1984, Ranjan et al. 2014, Ranjan et al. 2015, Ranjan et al. 2016, Singh et al. 2013, Singh et al. 2014).

There is no live birth after parthenogenetic embryo transfer in higher mammal. Recently, mammalian parthenogenesis has been achieved with the birth of the mouse Kaguya (Kono 2004). This has opened up the hope of making parthenogenesis a successful method of cloning in domestic animal. So far no comparative gene expression between parthenogenetic, female sexed IVF and *in vivo*
derived embryos has been done to identify the deficiency or molecular defects during normal parthenogenetic embryonic development and growth in goats. Scanty information is available in caprine (Singh et al. 2014, Ranjan et al. 2013a, 2013b) and further the comparison has been made of unknown sexes of IVF or in vivo derived embryos. When parthenogenetic embryos are compared with female sexed IVF or female sexed in vivo derived embryos then only the actual status of gene expression pattern can be stated. Keeping in view above information and gaps in knowledge, the present research work was proposed to be stated. Keeping in view above information and gaps in knowledge, the present research work was proposed to be stated.

MATERIALS AND METHODS

All the experiments were approved by ethics committee of this institute.

Embryos production and culture of embryonic cells isolated from early stage embryos: In vitro embryo production was done as per Ranjan et al. (2013a). For parthenogenetic diploid (DIP) embryo development, isolated oocytes were cultured in maturation media supplemented with 15 μg/ml of cytochalasin B (Ranjan et al. 2013a). Surgical embryo collection was done from 10 super ovulated goats as per standard protocol with Pluset® (Agrawal et al. 1982). The DIP, IVF and in vivo derived embryos of 8 to 16 cells and morula stages of DIP (36 and 37), IVF (20 and 22) and in vivo (6 and 5) derived female sexed embryonic cell colonies by Quick-RNA™ MicroPrep. cDNA was synthesized using iScript select cDNA Synthesis kit. Relative quantification of different genes was performed using a real time PCR method by using Bio-Rad CFXManager™ software and EvaGreen supermix as per standard protocol developed in our laboratory (Ranjan et al. 2014, Singh et al. 2014). The detail of primers is given in Table 1.

Statistical analysis: Relative expression of gene in fold changes was calculated by 2-ΔΔCT method (Pfaffl et al. 2002). The data was analyzed by one way ANOVA using SPSS 16 and a P-value <0.05 was considered to be significant.

RESULTS AND DISCUSSION

Three types of embryonic cell colonies (DIP, IVF and in vivo) and their 2 developmental stages (8–16 cell and morula) were used in the present study. The IVF and in vivo derived embryonic cell colonies were sexed with PCR and female sexed colonies were separated. Parthenogenetic embryonic cell colonies were karyotyped and diploid parthenogenetic colonies were separated. In vivo derived 8–16 cell and morula stage of embryonic cell colony were used as control for relative expression analysis. The results indicated that CCB (15 μg/ml) in maturation medium can be used for the production of optimum diploid parthenogenetic embryos in the caprine species (Ranjan et al. 2013a). The sex determination method of embryos can accurately and efficiently predict the sex of embryos. The overall sex ratio of male:female embryo was 1:1.18 (Ranjan et al. 2013b).

In the present study, beta-actin and GAPDH were used as housekeeping genes to study the relative expression of P57KIP2, Grb10, Xist and Dlk1. All developmental genes

| Primer      | Sequence (10 pmol/μl)                      | Annealing temp (°C) | Product size (bp) |
|-------------|--------------------------------------------|---------------------|-------------------|
| β-actin     | F 5’TTCATCACCATGCAGGCTGATG3' R 5’CCATCCACACGGAGATAC3' | 60                  | 286               |
| GAPDH       | F 5’GGAGGA ACC TGCCAAGTATG3' R 5’TGGATGTGCCTGGTGAAGTC3' | 60                  | 126               |
| P57KIP2     | F 5’GACGCAGGTTCGGTTCTGGTATT3' R 5’CCATGTCCTCCTTGGGCAGAAT3' | 60                  | 97                |
| Grb10       | F 5’ATGAGTTGGCTCTGGAGATC3' R 5’CTGCTGACTCTGTTGAAGTC3' | 60                  | 253               |
| Xist        | F 5’TGGTTCGTCGGAGAATATGCCCTG3' R 5’GATGCAAAGCCGCCAAGAATGTA3' | 56                  | 112               |
| Dlk1        | F 5’GGCATCGTCTCCCTCAACAAG3' R 5’GCAGCAGCGTTCTCTTCTCC3' | 60                  | 88                |
| Sry         | F 5’TGGACGAAGCGAAAGGTGGCT3' R 5’ATCGAGGACGTGIGACGCAGCATAAT3' | 60                  | 342               |

The female sexed colonies of IVF and in vivo derived embryos of cultures were used for gene expression studies.

RNA extraction and real time polymerase chain reaction: The total RNA was isolated from embryonic cell colony generated from 8 to 16 and morula stages of DIP (36 and 37), IVF (20 and 22) and in vivo (6 and 5) derived female sexed embryonic cell colonies by Quick-RNA™ MicroPrep. cDNA was synthesized using iScript select cDNA Synthesis kit. Relative quantification of different genes was performed using a real time PCR method by using Bio-Rad CFXManager™ software and EvaGreen supermix as per standard protocol developed in our laboratory (Ranjan et al. 2014, Singh et al. 2014). The detail of primers is given in Table 1.
were expressed in all the samples tested in present study. The expression of P57KIP2, growth factor receptor-bound protein 10 (Grb10) and X-inactive specific transcript (Xist) was upregulated significantly (P<0.05) in both stages of DIP as compared to IVF and in vivo one (Figs 1,2). There was no significant difference (P>0.05) in P57KIP2 gene expression between 8–16 and morula of DIP, IVF and in vivo derived embryonic cell colony (Figs 1, 2). At 8–16 cell stage, there was no significant difference between DIP and IVF embryos, but in morula-stage, DIP embryos had significantly (P<0.05) upregulated expression of Grb10 gene (Figs 1,2). Interestingly, at 8–16 cell stage, IVF embryos had significantly upregulated expression of this gene like DIP, but in morula stage, the difference was non significant albeit comparatively higher expression in IVF one. There was no significant difference between two stages of DIP and in vivo (P>0.05) but morula of IVF showed significantly lower (P<0.05) expression than 8–16 cell stage (Fig. 1). There was significantly higher (P<0.05) Xist expression in morula stage of DIP and in vivo derived embryos as compared to 8–16 cell stage but no significant difference between two stages of IVF embryos (Figs 1, 2). The expression of delta-like1 (Dlk1) was downregulated significantly (P<0.05) in 8–16 stage of DIP embryos as compared to in vivo and IVF derived one of similar stage (Figs 1, 2). However, there was no significant (P>0.05) difference in both stages between IVF and in vivo derived embryos (Figs 1, 2). In morula stage, the expression of this gene was not significantly different among different types of embryos (Figs 1, 2). When compared between 8–16 and morula stage, there was no significant difference (P>0.05) in expression of this gene in DIP, IVF and in vivo derived embryonic cell colony (Figs 1, 2).

P57KIP2 is a structurally distinct member of the p21Cip1 Cdk inhibitor family and is a candidate tumor suppressor gene. This gene lies –800 kb from Igf2 in both mouse and human and is a potent, tight-binding inhibitor of several G1 cyclin/Cdk complexes (Simon et al. 2011). This gene is expressed maternally in all mammalian species examined to date. The function of this gene is dependant with the expression of Igf2 gene and infant both the genes work in opposing manners to control cell proliferation during development (Zhang et al.1997). It is down regulated in mice with high serum levels of Igf2 and its expression is reduced in Igf2 treatment of embryo fibroblast (Grandjean et al. 2000). P57KIP2 embryos were overgrown at E15.5 and at E18.5, just prior to birth but there was no difference in the weight of mutant and wild-type pups after birth (Simon et al. 2011). It is a maternally expressed gene and supported the prediction of the parental conflict hypothesis that the paternal genome silences genes that have an inhibitory role in embryonic growth (Andrews et al.2007). Grb10 is maternally expressed in most tissues and known to bind the insulin and insulin like growth factor 1 (Igf-1) receptors. It was detected both in IVF and parthenogenetically activated (PA) blastocysts (Ruddock et al. 2004) as well as in vivo derived blastocysts in bovine (D’Cruz et al. 2008). It was observed that it is also expressed in human blastocyst, but so far no evidence could be provided for an allele specific expression (Adjaeye et al. 2005). A study showed that this gene is expressed biallelically in ovine and porcine blastocyst (Thurston et al. 2008, Park et al. 2011). We also observed high expression of Grb10 in DIP as compared to in vivo and IVF samples. Xist transcripts were first detected at the 16–32-cell stage embryos, then detected in all morula and in 2 of 6 blastocysts (Ruddock et al. 2004) and in both male and female morulae and in female blastocysts in bovine (Peippo et al. 2002). In porcine it is expressed in preimplantation IVF and parthenogenetic embryos and are biallelically expressed (Park et al. 2011), while in mouse it shows monoallelic expression (Latham 2005). The expression of Xist RNA appeared to be elevated in haploid androgenetic blastocysts relative to diploid androgenetic and fertilized controls, but expression was quite variable and the difference was not statistically significant (Latham et al. 2002). In bovine, this gene displayed complete imprinting with expression in in vivo and parthenogenetic embryos in bovine (D’Cruz et al. 2008). The above results indicated
that this gene is expressed in preimplantation embryos in many species and have elevated expression as compared to in vivo derived embryos. However, no comparative expression profile has been studied among DIP, IVF and in vivo derived embryos. We also observed the expression of P57KIP2, Grb10 and Xist in all stages of parthenogenetic, in vivo and IVF derived embryonic cell colony. The expression was upregulated significantly (P<0.05) in DIP compared to their in vivo and IVF derived embryonic cell colony.

Dlk1 mRNA was expressed in mouse embryos during post implantation development, beginning between embryonic day 7 and day 11, as well as in the adult pancreas, bone marrow, adrenal, and pituitary glands (Schmidt et al. 2002). It has also been seen to express at high levels in the mouse embryo and placenta during development (Schmidt et al. 2002). However, the expression of this gene could not be detected in any of the oocyte or embryo samples of bovine (Ruddock et al. 2004). In this study, we observed a very low level of expression of this gene in DIP compared to IVF and in vivo embryos of caprine.

The results indicated that in caprine, the expressions were either low or enhanced in DIP as compared to IVF or in vivo derived embryos. The in vitro culture condition affects gene expression (Doherty et al. 2000, Khosla et al. 2001). Therefore, the changes of relative expression of genes in DIP and IVF embryos in the present study might be due to the effect of in vitro culture condition. Several in vitro developmental defects have been reported in parthenogenetic embryos compared with fertilized embryos (Loi et al. 1998). It was reported earlier that the fetus death may be due to lack of formation of placenta or perturbed developmental gene expression (Ranjan et al. 2013c, Renu et al. 2014, Ranjan et al. 2014, Kharche et al. 2015). The sequential expressions of developmental related genes are required for normal mammalian development in utero (Thomson et al. 1989, Nishita et al. 1996).

The expression profile of both paternal and maternally imprinted genes were perturbed, which may be responsible for developmental failure of parthenogenetic embryos in this species and warrants further modification of protocol for generation of DIP embryos in Capra hircus.

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REFERENCES

Adjaye J, Huntriss J, Herwing R, BenKahla A and Brink T C. 2005. Monoallelic expression of nine imprinting genes in the sheep embryo occurs after the blastocyst stage. Reproduction 135: 29–40.

Agrawal K P, Mongha I V and Bhattacharya N K. 1982. Collection and transfer of embryos in goats: surgical methods. Indian Veterinary Journal 59: 298–303.

Andrews S C, Wood M D, Tunster S J, Barton S C, Surani M A and John R M. 2007. Cdkn1c (P57KIP2) is the major regulator of embryonic growth within its imprinted domain on mouse distal chromosome 7. BMC Developmental Biology 21(7): 53.

Barton S C, Surani M A and Noris M L. 1984. Role of paternal and maternal genomes in mouse development. Nature 311: 774–76.

D’Cruz N T, Katrina A E, Wilson J A, Melissa A, Cooney A, Tayfur R, Tecirlioglu B, Irima L C, Cesar G C, Michael K, Holland A and Andrew J F A. 2008. Putative imprinted gene expression in uniparental bovine embryo models. Reproduction, Fertility and Development 20: 589–97.

Doherty A S, Mann M R, Trembly K D, Bartolomei M S and Schultz R M. 2000. Differential effects of culture on imprinted H19 expression in the preimplantation mouse embryo. Biology of Reproduction 62: 1526–35.

Grandjean V, Smith J, Schofield P N, Ferguson and Smith A C. 2000. Increased Igf2 protein affects P57KIP2 expression in vivo and in vitro implications for Beckwith-Wiedmann syndrome. Proceedings of the National Academy of Sciences USA 97: 5279–84.

Kauffman M H, Barton S C and Surani M A H. 1977. Normal postimplantation development of mouse parthenogenetic embryos to the forelimb bud stage. Nature 265: 53–55.

Kharche S D, Goel A K, Jindal S K, Ranjan R, Rout P K, Agarwal S K, Goel P, Saraswat S, Viji R K, Malakar D, Sadhan Bag, Sarkhel B and Bhanja S K. 2014. Development of parthenote following in vivo transfer of embryos in Capra hircus. In Vitro Cellular and Developmental Biology-Animal 50(10): 893–98.

Khosla S, Dean W, Brown D, Reik W and Feil R. 2001. Culture of preimplantation mouse embryos affects fetal development and the expression of imprinted genes. Biology of Reproduction 64: 918–26.

Kono T. 2004. Genomic imprinting is a barrier to parthenogenesis in mammals. Cytogenetics Genome Research 113: 31–35.

Latham K E, Hidenori A, Patel B and Yanagimachi R. 2002. Comparison of gene expression during preimplantation development between diploid and haploid mouse embryos. Biology of Reproduction 67: 386–92.

Latham K E. 2005. X chromosome imprinting and inactivation in preimplantation mammalian embryos. Tsai Genetics 21: 120–27.

Loi P, Ledda S, Fulka J J, Cappai P and Moor R M. 1998. Development of parthenogenetic and cloned ovine embryos: effect of activation protocols. Biology of Reproduction 58: 1177–87.

Nishita Y, Yoshida I, Sado T and Takagi N. 1996. Genomic imprinting and chromosomal localization of the human Mest gene. Genomics 36: 539–42.

Park T, Han-Je Y, Park T S and Han J Y. 2011. Derivation and characterization of pluripotent embryonic stem cells in chicken. Molecular Reproduction and Development 80(4): 475–82.

Peippo J, Farazmand A, Kurkilaiti M, Markkula M, Basrur P K and King W A. 2002. Sex-chromosome linked gene expression in in vitro produced bovine embryos. Molecular Human Reproduction 8(10): 923–29.

Pfäffli M W, Graham W, Horgen L and Dempfle L. 2002. Relative expression software tool (RESCUT) for group wise comparison and statistical analysis of relative expression results in real time PCR. Nucleic Acid Research 30: 62–66.

Puri G, Kumar Kuldeep, Singh Renu, Singh R K, Yasotha T, Ranjan R, Kumar Manish, Das B C, Singh G, Sarkar M and Bag Sadhan. 2012. Effects of growth factors on establishment
and propagation of embryonic stem cells from very early stage IVF embryos and their characterization in buffalo. *International Journal of Stem Cells* 5(2): 96–103.

Ranjan R, Singh R K, Yasotha T, Kumar Manish, Puri Gopal, Kumar Kuldeep, Singh Renu, Bhure Sanjev, Malakar D, Bhanja S K, Sarkar M, Das B C and Bag Sadhan. 2013a. Effect of actin polymerization inhibitor during oocyte maturation on parthenogenetic embryo development and ploidy in *Capra hircus*. *Biochemical Genetics* 51(11–12): 944–53.

Ranjan R, Das B C and Bag Sadhan. 2013b. Molecular sexing of IVF and in vivo derived embryonic cell colony in goat. *Indian Journal of Animal Sciences* 51(10): 1039–41.

Ranjan R, Singh R K, Yasotha T, Kumar Manish, Kumar Kuldeep, Singh Renu, Houque M, Mourya V P, Gyanendra Singh, Sarkar M, Das B C and Bag Sadhan. 2013c. Survivability of parthenogenetic embryos following in vivo transfer in naturally synchronized *Capra hircus*. In *vitro Cellular and Developmental Biology—Animal* 49: 486–91.

Ranjan R, Singh Renu, Kumar Kuldeep, Sarkar M, Das B C and Bag Sadhan. 2014. Necdin and neuronatin genes expression among diploid parthenogenetic, IVF and in vivo derived female sexed embryos during preimplantation development in goat. *Indian Journal of Animal Sciences* 84(8): 34.

Ranjan R, Singh Renu, Kumar Kuldeep, Sarkar M, Das B C and Bag Sadhan. 2015. Expression profile of H19 and Peg1 among diploid parthenogenetic, female sexed IVF and in vivo derived embryos during pre-implantation development in goat. *Indian Journal of Animal Sciences* 85(11): 1199–1201.

Ranjan R, Singh Renu, Kumar Kuldeep, Sarkar M, Das B C and Sadhan Bag. 2016. Insulin like growth factor 2 (Igf2) and its receptor gene (Igf2r) showed opposite expression in diploid parthenogenetic embryos in *Capra hircus*. *Indian Journal of Animal Sciences* 86(1): 45–48.

Ruddock N T, Wilson K J, Cooney M A, Korflatis N A, Tecirlioğlu R T and French A J. 2004. Analysis of imprinted messenger RNA expression during bovine preimplantation development. *Biology of Reproduction* 70: 1131–35.

Schmidt J V, Matteson P G, Jones B K, Guan X J and Tilghman S M. 2002. The Dlk1 and Gtl2 genes are linked and reciprocally imprinted. *Genes Development* 14: 1997–2000.

Simon J, Tunster M, Van de P and Rosalind M J. 2011. Fetal overgrowth in the Cdkn1c mouse model of Beckwith-Wiedemann syndrome. *Disease Models and Mechanisms* 4: 814–21.

Singh Renu, Kumar Kuldeep, Khan Iram, Ranjan R, Yasotha T, Singh R K, Das B C and Bag Sadhan. 2013. Comparative expression profile of developmental related genes in haploid and diploid parthenogenetic embryos in caprine. *Indian Journal of Animal Sciences* 83(5): 502–05.

Singh Renu, Kumar Kuldeep, Ranjan R, Kumar Manish, Yasotha T, Singh R K, Das B C and Bag Sadhan. 2014. Comparative expression analysis of embryonic development related gene at different stages of parthenogenetic and in vitro fertilized embryos in caprine. *Zygote* 23(2): 198–204.

Thomson J A, Itskovitz-Eldor J, Shapiro S S, Waknitz M A, Swiergiel J J, Marshal V S and Jones J M. 1989. Embryonic stem cell lines derived from human blastocyst. *Science* 282: 1145–47.

Thurston A, Taylor J, Gardner J, Sinclair K D and Young L E. 2008. Monoallelic expression of nine imprinted genes in the sheep embryo occurs after the blastocyst stage. *Reproduction* 135: 29–40.

Zhang P, Liegeois N J, Finegold M, Hou H and Thompson J C. 1997. Altered cell differentiation and proliferation in mice lacking p57(KIP2) indicates a role in Beckwith-Wiedemann syndrome. *Nature* 387: 151–58.