Comp Clin Pathol (2012) 21:1305–1312
DOI 10.1007/s00580-011-1286-4

ORIGINAL ARTICLE

Gestational variations in the biochemical composition of the fetal fluids and maternal blood serum in goat

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Received: 20 August 2010 / Accepted: 8 July 2011 / Published online: 19 July 2011

Abstract The purpose of this study was to determine the values of some metabolites, ions, and enzymes in maternal blood serum and fetal fluids in relation to pregnancy stage in singleton pregnant goats. Gravid uteri of goats were collected from local abattoirs. The allantoic and amniotic fluids as well as maternal blood samples were collected. Fetal age was determined according to crown–rump length by applying the age estimation formula that previously was presented for goat. The pregnancies were divided into five stages as: stage I (0–30 days), stage II (31–60 days), stage III (61–90 days), stage IV (91–120 days), and stage V (121 days to term). With the progress of pregnancy, the biochemical levels of fetal fluids and maternal serum changed as follows: there was a rise of total protein, urea, and creatinine concentrations in fetal fluids and serum; the level of glucose in serum, potassium, and ALK in fetal fluids and calcium and phosphorus in allantoic fluid increased; triglyceride and sodium contents of fetal fluids and serum decreased; glucose in fetal fluids, AST and LDH in serum and allantoic fluid, potassium and ALT in serum, and calcium and phosphorus in amniotic fluid and serum dropped; the values of AST, ALT, and ALK in amniotic fluid remained unchanged; and the levels of cholesterol and LDH in amniotic and allantoic fluids were constant in the whole gestation periods. The serum cholesterol value showed a significant decrease from stages 1 to 2 of pregnancy. But, it was not significant from stages 2 to 5 of gestation.

Keywords Biochemical composition · Gestation · Fetal fluids · Maternal serum

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Introduction

Dynamic system of fetoplacental unit causes constant exchange of water and fluid constituents between fetal fluid compartments and the maternal circulation, which is reflected in changes in the physical, chemical, and biochemical constituents of fetal fluids (Aidasani et al. 1993). The developing fetus, surrounded by the amniotic fluid compartment and connected with the allantoic sac via the urachus and placental vasculature, receives nutrients mainly via the umbilical vein (Battaglia and Meschia 1988).

In cattle and sheep, formation of amnion occurs on 13–16 days of pregnancy and then the amniotic fluid fills the amniotic sac (Robert 1986). The amniotic fluid provides a unique aqueous environment in which the fetus develops symmetrically. When it is swallowed, amniotic fluid is a significant source of nutrients for the fetus (Schmidt 1992). In contrast, the allantoic sac was traditionally considered to be a reservoir for fetal wastes (Alexander and Williams 1968). Aidasani et al. (1992) reported that fetal fluid composition in mammals is influenced by the excretion of fetal urine and that changes in the concentration of many components during late pregnancy may reflect fetal metabolic activity. A broad knowledge of amniotic fluid is of the utmost importance in understanding fetal metabolism and identifying pathological conditions during pregnancy (Prestes et al. 2001).

The study of biochemical profiles both in maternal serum and fetal fluids is a tool for pregnancy diagnosis and the status of growing fetus. Blood biochemical evaluation plays an important role in diagnosis of disease. Serum biochemical parameters varied widely, and preferably glucose and urea individually or in combination are the useful parameters in the diagnosis of physiological and pathological conditions in ewes. Glucose as a source of energy is necessary for production and reproduction performance (Radostits et al. 2000). It is the major metabolite used by the sheep fetus, and the energy requirements of the ewe increase during late pregnancy due to rapid growth of the fetus (Firat and Ozpinar 2002). The concentration of glucose in ewes has been reported between 35 and 45 mg/dl (Nelson and Guss 1992) and could be affected by physiological (Firat and Ozpinar 1996) and disease conditions (Symonds et al. 1986; Ford et al. 1990). The presence of significant correlations among serum parameters including glucose, betahydroxybutyrate, cholesterol, total protein concentrations, and urea in nonpregnant ewes could be useful to compare with values in late pregnant ewes in order to study need of the dam and pregnancy toxemia (Nazifi et al. 2002; Ramin et al. 2005). Therefore, understanding the normal values would be the useful index in the determination of the physiological aspects in nonpregnant or pregnant ewes.

Biochemical profiles also carry important route not only during prenatal development but also during neonatal or postnatal period. Determination of normal values is important for the clinical interpretation of laboratory data. These indices may vary depending on factors such as sex, age, weather, stress, season, and physical exercise (Kaneko et al. 1999). Mufti et al. (2000) reported that as the gestation age advanced, marked changes occur in total protein, glucose, urea, and creatinine in allantoic, amniotic, and maternal serum in ewe. Activity of enzymes like aspartate aminotransferase, alanine aminotransferase, and alkaline phosphatase was studied by Chauhan and Tiwari (1996) in the amniotic fluids of goat. Mellor and Slater (1973), studying aspects of fetal fluid physiology in ovine, found that entry of urine into fluid sacs tends to decrease osmolarity concentrations of sodium, potassium, chloride, and glucose in both fluids, the amino acid concentration in the allantoic fluid, and also increase fructose and urea concentrations in both fluids. Aidasani et al. (1992) reported that fetal fluid composition in mammals is influenced by the excretion of fetal urine and that changes in the concentration of many components during late pregnancy may reflect fetal metabolic activity. Reddy et al. (1995) performed biochemical studies in ewe amniotic fluid at different stages of pregnancy, obtaining significant differences in mean levels of glucose. They concluded that decreased glucose levels at the end of pregnancy might have been caused by fetal intake of glucose due to the development of the fetal swallowing reflex. A broad knowledge of amniotic fluid is of the utmost importance in understanding fetal metabolism and identifying pathological conditions during pregnancy. The present study was carried out to determine the values of some metabolites, ions, and enzymes in blood serum and amniotic and allantoic fluids during different months of singleton goat pregnancy.

Material and methods

For this study, 108 gravid uteri of singleton pregnant goats were collected randomly from local abattoirs. The organs were removed immediately after slaughter, placed in crushed ice, and quickly taken to the laboratory. For collection of allantoic and amniotic fluids, the gravid uteri were cut open through the dorsal curvature without damaging the fetal sac. The allantoic and amniotic fluids were collected by 10-ml disposable syringes and stored in labeled plastic tubes at −20°C until biochemical analysis. Jugular blood samples were collected from dams in sterile glass tubes. These tubes were placed in an icebox and were carried to the laboratory. In the laboratory, these samples were centrifuged at 3,000 rpm for 15 min; the serum was separated and stored at −20°C for further analysis. After collection of fetal fluids, fetuses were expelled from enclosing membranes and the fetal ages were determined by applying the age estimation formula: $Y=2.74X+30.15$, presented by Gall et al. (1994), where Y denotes the developmental age in days and X is the crown–rump length in centimeters. The pregnancies were divided into five stages as: stage I (0–30 days), stage II (31–60 days), stage III (61–90 days), stage IV (91–120 days), and stage V (121 days to term). The serum and fetal fluid samples were analyzed for various metabolites (glucose, urea, creatinine, total protein, cholesterol, and triglycerides), ions (calcium, phosphorus, sodium, and potassium), and enzymes [alkaline phosphatase (ALK), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and lactate dehydrogenase (LDH)] using commercially available kits by photometer method on an AutoAnalyzer (RA-1000, Technicon).

Statistical analysis

The mean values (±SE) for concentrations of various biochemical compositions of fetal fluids and blood serum were computed. To see the magnitude of gestation age variation in concentrations of various biochemical constituents of fetal fluids and serum, the data were subjected to one-way analysis of variance. Significance between means was tested using Duncan's multiple range test. The correlations between fetal age and biochemical concentrations of fetal fluids as well as maternal serum were analyzed by Pearson's bivariate correlation test (Petrie and Watson 2006).

Results

The values of biochemical concentrations of amniotic and allantoic fluids as well as maternal serum at various months of singleton pregnancy in goat are given in Tables 1, 2, and 3. Mean values of glucose, triglyceride, and sodium both in amniotic and allantoic fluids decreased significantly with advancement of pregnancy. Contrariwise, total protein, urea, creatinine, and potassium concentrations of fetal fluids were higher in advanced pregnancies when compared with the earlier gestations. The calcium and phosphorus levels of allantoic fluid in advanced pregnancy were higher than earlier gestation periods; it was contrariwise in amniotic fluid. The concentrations of glucose, total protein, creatinine, and alkaline phosphatase in maternal serum increased as the gestation period progressed. Contrariwise, statistical analysis of cholesterol, triglyceride, sodium, potassium, calcium, phosphorus, AST, ALT, and LDH in maternal serum revealed decreasing values as gestation advanced. Cholesterol, AST, ALT and ALK contents of amniotic fluid and cholesterol, and ALT and LDH values of allantoic fluids were not different among the various stages of pregnancy.

The correlations between fetal age and metabolite, enzyme and ion concentrations of fetal fluids and maternal serum are presented in Tables 4, 5, and 6. Except for cholesterol and ALT in both amniotic and allantoic fluids and AST in amniotic fluid, there was a significant correlation between gestation age and biochemical values of fetal fluids and maternal serum.

Discussion

In this study, the significant increasing trend in glucose level in advanced pregnancy in maternal blood serum while decreasing trend in amniotic and allantoic fluids with the advanced pregnancy was observed. These results were in agreement with earlier results by Khatun et al. (2011) and Mufti (1995) in sheep. Also, decreasing the glucose concentration in amniotic fluid from early to late stages of gestation was similar to results of Khadjeh et al. (2007) in goat, Oliveira et al. (2002) in human, and those recorded in sheep by Prestes et al. (2001), Bradley and Mistretta (1973), and Reddy et al. (1995), but was different from those reported by Aidasani et al. (1992) in goat and Tangalakis et al. (1995) in sheep. For all stages of gestation, the concentration of glucose in maternal serum was much higher in comparison to fetal fluids. The increase of glucose value in maternal serum with advancing the gestation was also in agreement with those of Baetz et al. (1976) in cattle, Lathura et al. (1987) in swine,

Table 1 Values of metabolite constituents of fetal fluids and maternal serum during different stages of gestation in goat

Composition	Types of fluid	Stages of pregnancy				
		Stage 1 (0–30 days), *n*=23	Stage 2 (31–60 days), *n*=31	Stage 3 (61–90 days), *n*=27	Stage 4 (91–120 days), *n*=15	Stage 5 (121–150 days), *n*=12
Glucose (mg/dl)	Amniotic fluid	5.99±0.43c	5.39±0.39bc	4.85±0.52b	2.57±0.52a	1.69±0.15a
	Allantoic fluid	5.42±0.33b	4.87±0.49b	4.48±0.45b	2.19±0.17a	1.52±0.14a
	Maternal serum	18.12±1.66a	27.68±2.11bc	24.61±1.76b	32.07±1.19cd	33.09±0.76d
Total protein (mg/dl)	Amniotic fluid	33.02±1.50a	32.60±1.44a	42.08±1.54b	53.89±1.83c	56.12±2.26c
	Allantoic fluid	38.45±2.13ab	35.66±1.45a	44.77±2.69b	59.01±2.79c	63.73±3.52c
	Maternal serum	44.84±1.49ab	41.27±2.80a	52.10±3.12b	68.14±2.14c	77.48±4.33d
Cholesterol (mg/dl)	Amniotic fluid	2.73±0.44a	2.92±0.56a	2.58±0.71a	3.02±0.38a	2.30±0.33a
	Allantoic fluid	2.64±0.35a	2.91±0.46a	2.98±0.53a	2.50±0.35a	2.38±0.18a
	Maternal serum	115.96±6.92b	88.28±6.62a	87.98±2.92a	85.02±14.78a	85.92±4.73a
Triglyceride (mg/dl)	Amniotic fluid	17.83±1.93c	15.55±1.54bc	11.77±1.18ab	10.11±0.88a	9.56±1.18a
	Allantoic fluid	23.31±2.18c	17.92±1.61b	13.90±1.14ab	12.39±0.76a	11.83±1.34a
	Maternal serum	28.12±3.15c	22.49±1.81bc	20.54±1.39ab	15.96±0.90a	14.95±1.71a
Urea (mg/dl)	Amniotic fluid	29.85±5.61a	32.70±5.72a	33.54±5.52a	57.54±2.95b	73.12±2.81c
	Allantoic fluid	37.77±5.72a	39.22±4.88b	47.31±6.84ab	61.65±2.72b	86.31±4.05c
	Maternal serum	48.03±4.35a	46.58±4.80a	57.89±5.82a	80.57±4.62b	102.73±8.11c
Creatinine (mg/dl)	Amniotic fluid	1.86±0.23a	2.06±0.26a	3.34±0.30b	5.40±0.46c	6.15±0.32c
	Allantoic fluid	5.54±0.75a	8.25±0.60b	6.66±0.59ab	11.89±0.73c	13.72±0.80c
	Maternal serum	6.86±0.56a	9.72±0.63b	8.85±0.42b	13.25±0.70c	16.04±0.54d

Mean±SE values with different lowercase letters in the same row differ significantly ($p<0.05$)

Table 2 Values of ion constituents of fetal fluids and maternal serum during different stages of pregnancy in goat

Composition	Types of fluid	Stages of pregnancy				
		Stage 1 (0–30 days), n=23	Stage 2 (31–60 days), n=31	Stage 3 (61–90 days), n=27	Stage 4 (91–120 days), n=15	Stage 5 (121–150 days), n=12
Sodium (mmol/L)	Amniotic fluid	123.34±3.69bc	128.61±5.62c	110.70±3.80b	92.78±5.25a	80.83±6.59a
	Allantoic fluid	70.38±3.70c	67.22±3.04c	75.42±6.50c	44.27±3.01b	30.40±2.31a
	Maternal serum	132.55±4.79cd	142.86±6.34d	125.60±2.25c	104.97±5.09b	87.66±5.67a
Potassium (mmol/L)	Amniotic fluid	2.44±0.27b	2.00±0.11a	4.08±0.73ab	4.55±0.91b	5.66±0.96b
	Allantoic fluid	2.16±0.28ab	1.51±0.16a	3.50±0.64bc	3.65±0.73bc	4.38±0.74c
	Maternal serum	3.97±0.67c	3.15±0.71bc	3.03±0.57bc	1.95±0.26a	1.11±0.13a
Calcium (mmol/L)	Amniotic fluid	5.02±0.34c	4.76±0.41bc	3.98±0.39bc	3.76±0.36b	2.28±0.22a
	Allantoic fluid	8.97±0.64a	10.61±0.49ab	10.79±0.65ab	12.45±1.15b	12.71±0.52b
	Maternal serum	9.85±0.63d	9.17±0.43cd	8.30±0.35bc	7.41±0.54ab	6.73±0.38a
Phosphorus (mmol/L)	Amniotic fluid	6.16±0.55c	5.52±0.48bc	4.75±0.33b	3.21±0.23a	3.42±0.34a
	Allantoic fluid	7.49±0.54a	7.09±0.47a	9.20±0.54bc	9.83±0.68c	10.04±0.73c
	Maternal serum	12.00±0.77c	11.22±0.43bc	10.80±0.51bc	9.60±0.65ab	7.85±0.65a

Mean±SE values with different lowercase letters in the same row differ significantly ($p<0.05$)

and McCrabb et al. (1991) in sheep. Decrease of glucose in amniotic fluid during gestation may be due to fetal intake of glucose as a consequence of the fetal swallowing reflex (Prestes et al. 2001). According to Bauman and Curri (1980), glucose from the maternal circulation is the main energy source for the fetus during pregnancy in farm animals and it comprised 50–70% of total substrates oxidized by the fetus.

The content of total protein in fetal fluids and maternal serum increased as the gestation period progressed. Similar results were recorded by Khatun et al. (2011) in sheep and Kaneko and Corneleous (1970) in several domestic animals. Unlike our results, Khadjeh et al. (2007) stated that in sheep, the highest value of total protein in amniotic fluid was in stage 1 of pregnancy and then decreased with advancing the gestation stages. The increased protein concentration in maternal circulation indicates a positive association with pregnancy establishment (McDonald 1980). The low concentration of total protein in amniotic fluid could be attributed to the absence of fibrinogen and other proteins due to fetal liver immaturity (Reddy et al. 1995). The higher level of total protein in the maternal

Table 3 Values of enzyme constituents of fetal fluids and maternal serum during different stages of gestation in goat

Composition	Types of fluid	Stages of pregnancy				
		Stage 1 (0–30 days), n=23	Stage 2 (31–60 days), n=31	Stage 3 (61–90 days), n=27	Stage 4 (91–120 days), n=15	Stage 5 (121–150 days), n=12
AST (IU/L)	Amniotic fluid	10.13±1.08a	9.11±1.17a	8.24±0.84a	7.23±0.74a	9.48±0.68a
	Allantoic fluid	20.12±2.38a	18.86±3.64a	10.81±1.04b	10.23±0.75b	7.98±0.79b
	Maternal serum	111.60±6.53d	93.99±3.44c	72.69±4.27b	54.04±1.57a	52.17±4.40a
ALT (IU/L)	Amniotic fluid	2.30±0.24a	2.16±0.34a	2.36±0.22a	2.12±0.38a	1.89±0.26a
	Allantoic fluid	5.50±0.35a	5.35±0.55a	5.42±0.44a	5.36±0.40a	5.17±0.35a
	Maternal serum	57.77±2.90d	47.61±2.19c	34.80±2.71b	27.54±1.42a	23.80±1.45a
ALK (IU/L)	Amniotic fluid	44.69±2.41a	47.42±3.68a	45.00±3.20a	50.92±3.62a	49.84±3.42a
	Allantoic fluid	47.57±2.72a	46.49±3.50a	44.56±2.44a	53.73±3.33ab	58.28±3.89b
	Maternal serum	71.53±3.10ab	66.00±3.65a	79.64±2.85b	91.20±2.89c	97.35±4.66c
LDH (IU/L)	Amniotic fluid	34.36±2.28a	39.55±3.01a	43.89±2.02a	41.11±3.42a	40.54±4.01a
	Allantoic fluid	90.42±2.93c	82.81±4.99bc	72.42±7.05b	54.46±4.21a	46.89±2.74a
	Maternal serum	140.49±4.21a	131.02±5.09b	108.07±4.55c	76.60±5.72d	78.38±5.93d

Mean±SE values with different lowercase letters in the same row differ significantly ($p<0.05$)

Table 4 Correlation between fetal age and metabolite concentrations of fetal fluids and maternal serum in goat

	Glucose			Protein			Cholesterol			Triglyceride			Urea			Creatinine		
	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS
Fetal age	−0.87*	−0.85*	−0.75*	0.89*	0.83*	0.80*	−0.09, ns	−0.14, ns	0.40**	−0.69*	−0.73*	−0.72*	0.78*	0.80*	0.81*	0.89*	0.81*	0.87*

AMF amniotic fluid, *ALF* allantoic fluid, *MS* maternal serum, *ns* nonsignificant

$*p<0.01$; $**p<0.05$

serum than in the amniotic fluid is confirmed by the earlier findings in rabbit (Ozegbe 2005) and in women (Nusbaum and Zettner 1973). The lower total proteins in the amniotic fluid relative to the maternal plasma might have resulted from the metabolic activities and the maturation of the fetal renal glomerular function during the later stages of gestation, as reported by Gulbis et al. (1998). Brzenzinski et al. (1964) concluded that fetal circulation is the main source of amniotic fluid proteins. Sutcliffe and Brock (1973) and Ozegbe (2005) stated that most of the proteins in the amniotic fluid are of maternal origin.

In this study, the cholesterol concentration in amniotic and allantoic fluids from stages 1 to 5 of pregnancy showed no significant differences that was similar to results of Khatun et al. (2011) and Mufti (1995) in sheep. The maternal serum cholesterol value showed a significant decrease from stages 1 to 2 of pregnancy. But, it was not significant from stages 2 to 5 of gestation. In all stages of pregnancy, the constant level of cholesterol in fetal fluids was serving the need for synthesis of progesterone (Mufti 1995). Ozpinodotnar and Finodotrat (2003) reported that plasma cholesterol concentration was not significantly different between pre-pregnancy, pregnancy, and early lactation periods in ewes. In whole gestation stages, the cholesterol level in maternal serum was much higher than that in amniotic and allantoic fluids. Unlike our results, Mufti (1995) reported that with the advancement of pregnancy in ovine, serum cholesterol level showed a decreasing trend.

The concentration of triglyceride in both fetal fluids and maternal serum decreased slowly from stages 1 to 5 of gestation. The triglycerides are the storage lipids of animals in the plasma where the body uses it mainly as fuel. The dam uses the plasma lipids during the second half of pregnancy when energy requirements increase tremendously (Ozegbe 2005).

Urea level in amniotic fluid and maternal serum were constant from stages 1 to 3 and then increased. Its concentration in allantoic fluid increased significantly from the early to late stages of pregnancy. Increased level of urea during pregnancy has been reported by Mufti et al. (2000) and Mellor and Slatter (1971) in sheep and Chauhan and Tiwari (1996) in swine. Our observations about urea level changes with advancing the gestation of goat are not in agreement with those reported by Prestes et al. (2001) in sheep, who reported decreasing value of urea on 70, 90, and 140 days of pregnancy. According to Mellor and Slatter (1972), urea concentration in fetal bladder increases during pregnancy. Wintour et al. (1986) stated that in midgestation, fetal urine high in urea and low in chloride enters the amniotic fluid, but the high permeability of the membranes allows equilibration with the extracellular fluid of mother and/or fetus. Late in gestation, fetal urine with high urea

Table 5 Correlation between fetal age and enzyme concentrations of fetal fluids and maternal serum in goat

	AST			ALT			ALK			LDH		
	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS
Fetal age	−0.19, ns	−0.69*	−0.89*	−0.20, ns	−0.10, ns	−0.91*	0.25, ns	0.50**	0.77*	0.28, ns	−0.83*	−0.88*

AMF amniotic fluid, *ALF* allantoic fluid, *MS* maternal serum, *ns* nonsignificant

*$p<0.01$; **$p<0.05$

and even lower chloride concentrations enters the amniotic fluid. At this time, neither urea can leave so readily nor can chloride enter. Thereby, equilibration with extracellular fluid cannot occur. This dynamic situation is continued. The fetus removes some amniotic fluid by drinking, and fetal urine continues to enter, which results in an increase in amniotic fluid urea and decrease in chloride.

Creatinine concentration of fetal fluids and maternal serum was higher in advanced pregnancies when compared with the earlier gestations. Similar results in amniotic fluid were reported by Prestes et al. (2001) in sheep, Oliveira et al. (2002) in human, and Lovell et al. (1995) in goat. Creatinine is an indicator of muscle mass as well as renal function (Ozegbe 2005). Renal maturity is defined by the increase in glomerular filtration and by the maturity of renal tubular cells that begin to express various tubular transporters over the months of gestation (Delpire et al. 1994; Oliveira et al. 2002). Glomerular filtration in the fetal kidney can be assessed by the concentrations of creatinine and urea in the amniotic fluid (Ring et al. 1991). The evaluation of renal maturity can also indicate fetal maturity (Lumbers 1984). In nonpregnant women, creatinine and urea are used to evaluate the complex functioning of human kidneys (Oliveira et al. 2002). Similar to our results, Aidasani et al. (1992) observed that the concentration of creatinine in the allantoic fluid was significantly higher than in the amniotic fluid in goat. The increased level of creatinine in pregnant animal serum as well as in fetal fluids has been explained by Stainer (1965). Lack of exchange of solutes from allantoic fluid may be the cause of the increase.

The concentration of sodium in amniotic and allantoic fluids as well as maternal serum and also potassium value only in serum decreased as the gestation period progressed, while potassium level of fetal fluids was higher in advanced pregnancies when compared with the earlier gestations. Prestes et al. (2001), through amniocentesis on 70, 100, and 145 days of pregnancy in sheep, reported that sodium and potassium values decrease from 70 to 145 days of pregnancy. The mineralocorticoid activity of intrauterine fetal maturity acts on fetal kidneys, increasing potassium and decreasing sodium concentrations in fetal urine (Prestes et al. 2001). According to Wintour et al. (1986), a classical sodium pump may be responsible and alterations in the relative permeability to sodium and potassium may affect the transport. Sodium reabsorption by the fetal kidneys at the end of pregnancy is about 85–95% of the filtered load. Therefore, the fetal urine is usually hypotonic compared to plasma, indicating very efficient resorption capacity in the collecting duct (Robillard et al. 1988; Oliveira et al. 2002). Our results are compatible with a larger resorption of sodium and lower concentrations in the amniotic fluid in the late stages of pregnancy, as already demonstrated by other authors (Brenner 1990). An almost complete development of the fetal kidneys with adequate functioning of all receptors that carry out transport in the renal cells would be expected to occur in the third trimester. For example, the Na–K–ATPase protein present in all tubular segments has a main role in sodium reabsorption. There is an increasing growth of this protein during renal development, which is also accompanied by a larger capacity of renal tubules to transport sodium and water (Oliveira et al. 2002). Potassium demonstrated a slightly increasing growth profile throughout gestation, confirming observations reported by Benzie et al. (1973). These results are in accordance with the maturation of distal and collecting tubules that are

Table 6 Correlation between fetal age and ion concentrations of fetal fluids and maternal serum in goat

	Sodium			Potassium			Calcium			Phosphorus		
	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS	AMF	ALF	MS
Fetal age	−0.79*	−0.76*	−0.79*	0.62*	0.56*	0.63*	−0.73*	0.62*	−0.72*	−0.75*	0.61*	−0.70*

AMF amniotic fluid, *ALF* allantoic fluid, *MS* maternal serum

*$p<0.01$

responsible for potassium handling by the fetal kidneys (Gamba et al. 1994).

The calcium and phosphorus concentrations of allantoic fluid in advanced pregnancy were higher than earlier gestation stages. It was contrariwise in amniotic fluid and maternal serum. Calcium and phosphorus are important in the development of fetal skeleton. Thus, it would be expected that the fetus in conserving them would excrete very little into the amniotic fluid. The change in calcium content of the allantoic fluids suggests an increasing excretion of fetal urine as gestation proceeds. This implies that the composition of the allantoic fluid reflects the developing metabolic activity of the fetus and the developing functional efficiency of its kidney (Ozegbe 2005). Wales and Murdoch (1973) reported that the concentration of calcium in amniotic fluid of ovine fetus decreased very slightly between days 31 and 44 and increased almost twofold in the allantoic fluid during the same period.

The value of ALK in fetal fluids was higher in advanced pregnancies when compared with the earlier gestations. The levels of AST and LDH in serum and allantoic fluid and ALT in serum were lower in advanced gestations than the earlier stages of pregnancy. The contents of AST, ALT, and ALK in amniotic fluid and LDH in amniotic and allantoic fluids were constant in all stages of pregnancy. In our study, a decreased level of AST and ALT enzymes in maternal serum is in agreement with the study carried out by Mahawar et al. (2004) in goat and Pouroucholtamane et al. (2005) in a female yak. Although lactate dehydrogenase, aspartate aminotransferase, alanine aminotransferase, and alkaline phosphatase enzymes were mainly drawn from the digestive and respiratory tracts into the amniotic cavity (Gulbis et al. 1998), their activities in the amniotic fluid are not clearly defined or understood, other than maintaining the metabolic requirements of the amnion (Ozegbe 2005). Changes in blood concentrations of glucose, urea, proteins, and enzymes may all reflect alterations in liver function during pregnancy. The subnormal or elevated levels of enzymes in fetal fluid and serum are one of the important tools to assess liver functioning and healthy state of pregnancy (Khatun et al. 2011).

Conclusion

It was concluded that the concentrations of glucose, urea, creatinine, total protein, cholesterol, triglycerides, calcium, phosphorus, sodium, potassium, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase in amniotic fluid, allantoic fluid, and maternal serum of singleton pregnant goats may be changed with advancing the gestation stages.

Acknowledgments The authors gratefully acknowledge Ramin Agricultural and Natural Resources University for the research funds.

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