ARC Journal of Animal and Veterinary Sciences (AJAVS)
Volume 2, Issue 3, 2016, PP 29-35
ISSN 2455-2518 (Online)
DOI: http://dx.doi.org/10.20431/2455-2518.0203004
www.arcjournals.org

Serum and Tissue Sodium (Na) and Potassium (k) Concentrations in Newborn, Growing and Adult Sheep

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Abstract: *Little is known of the physiological Na and K tissue changes from birth to adulthood in sheep and other livestock. The purpose of this study was to compare the changes in the sodium and potassium contents of liver, kidney and brain tissues in newborn lambs with those of growing and adult sheep tissues.*

Serum, Liver, kidney and brain tissue samples were taken from 32 newborn lambs, 20 growing lambs (mostly about 6 months), and 25 adult (2-6 years) from various farm locations of Central Trinidad. All mineral determinations were carried out on a Pye Unicam SP2900 Atomic Absorption Spectrophotometer.

Serum N and K levels were not significantly different ($P > 0.05$) in new born lambs compared with levels in growing lambs and adult sheep. Higher Na levels but lower K levels were found in liver, ($P<0.001$) and brain ($P<0.001$) tissues of new born lambs compared with levels in growing lambs and adult sheep. Only a few animals had concentrations within the expected ranges for liver Na (35-39 m.Eq/w.wt) and liver (78-86 m.Eq/w.wt). K: Na ratios in liver tissues were about the value expected for ruminants of 2:1 which contrasted with ratio of unity found in newborn lambs.

Preliminary indications from this study implied that not only was there a reversal of Na and K levels in liver but also in brain tissues of newborn compared with growing and adult sheep.

Keywords: *Liver, Kidney, Brain, Na and K levels*

1. Introduction

Sodium (Na^+) is the main cation of the extracellular fluid while Potassium ($K^{+)}$ is the main cation of the intracellular space (Vrzgula- 1991), because Na and K are osmotically active, blood and tissue concentrations are usually expressed in milliequivalents per litre (meq/L) or meq/kg (Fresh weight or Dry weight) (Michell- 1974). However, Na and K in sheep serum expressed in mg/L as within the ranges 3000-4000 and 220-240, respectively, controlled by hormones from the adrenals, kidney glomerular complex and tubular mechanisms. (Michell- 1974; Long et al., 1965).

Sodium deficiency can arise if there is a dietary deficiency of Na or water intake if lowered ultimately resulting in a decrease in the extracellular volume and simultaneously a rise in plasma protein (Vrzgula, 1991). In animals Na deficiency results in loss of appetite, a rise in the feed conversion ratio, weight loss, low milk yields and wool formation, enlargement of the adrenals and cardiac arrhythmia (Michell, 1985). Pertaining to K, Campbell and Roberts (1965) and Telle et al. (1964) found serum K levels to decline with decreasing K intakes. Reference levels for serum K are 220-240 mg/L (2.4-4.0 mmol/L (Suttle- 2010). Serum K levels, however, can decline from 183 to 131 mg/L and 164 to 98 mg/L respectively at declining K intakes (Telle et al; 1964). Serum K and Na levels found in newborn lambs are somewhat higher than levels found in older age groups (Long et al., 1965).

A relative balance of Na, K and chloride electrolyte concentrations in the last trimester of pregnancy and early lactation is maintained to ensure health of the mother, the fetus and neonate. Studies in pregnant heifer calves however, have shown that Na levels can fluctuate slightly between 136 mmol/L and 138 mmol/L with the highest level of 141 mmol/L occurring on the day of delivery (Skrzypczak et al. 2011). Banlahim (1984) noted that while plasma Na can remain high during pregnancy in desert sheep and goats, whereas Na declines during lactation in desert goats only. In Boer goats and German cross bred goats, however and regardless of parity, serum Na and K remained unchanged during the first 40 days of pregnancy (Samardžija et al.,2011).

Ninety percent of sodium is found extracellularly (Michell- 1974), whereas ten percent is found in soft tissues especially muscle and liver (Vrzgula- 1991). The mechanisms controlling sodium and potassium balances at tissue surfaces (gut, skeletal, muscle or kidney), or in plasma and interstitial fluids (extracellularly) are not fully understood (Field et al.- 1968). Notwithstanding, an energy consuming sodium pump mechanism (Na^+ (K^+ ATPase EZ 3.1.1.37) operates at tissue surfaces keeping sodium within and potassium outside cells (Michell- 1985).

Extracellular fluid volume either contracts or expands in response to sodium depletion deficit or sodium excess, hence maintaining plasma sodium levels within narrow ranges (140 -145 mmol/L) at most times (Suttle, 2010 Wieslaw et al; 2014). However, both plasma sodium and chloride changes proportionally with respect to fluid volume (Kaneko 1989).

The Antidiuretic Hormone (ADH) and thirst help to regulate water balance (hence Na and Cl) by preventing water loss or by increasing water intake appropriately. However, Aldosterone hormone is the main monitor of extracellular sodium and chloride balance. It conserves renal secretion of Na and Cl by promoting potassium output Michell 1979). Conversely, urinary Na excretion is enhanced at low K intakes (1— 2 g/kg DM), indicating some sort of hormonal imbalance. Alternatively at low Na intakes (0.4 0.6 g/kg DM) increased. Aldosterone output causes a fall of Na but a rise of K in saliva (Sinclair et al., 1968; Martens et al., 1987). Aldosterone is also responsible for the decline in faecal Na at low Na intakes (Michell et al., 1988), and for the colonic absorption of Na (Michell 1989). Moreover, decreases in salivary, urinary and faecal Na outputs are necessary to preserve sodium balance during Na deficit (Michell 1989).

The main route of Na excretion is through the urine (Payne et al., 1987). Nevertheless, (Michell-1985) showed that when feeding to NRC 2007 recommendations (1.0— 1.4 g/d) faecal losses are in sheep are most prominent; whereas at moderate intakes (0. 69 g/d) faecal losses are higher. Sodium is also secreted into milk and may be lost during profuse sweating in hot climates (Ammerman et al., 1983; Suttle 2010).

Like Na, chloride is the main extracellular anion. Chlorides are mainly excreted into urine and to a lesser extent in faeces or perspiration (NaC1). Like Na it is also secreted into milk (Kincaid, 1988; Vrzgula, 1991). Feeding of low chloride diets does not produce signs of a chloride deficiency due homeostatic mechanisms mainly from reduced urinary excretion (Burkhalter et al; 1979).

There seems to be no clear hormonal mechanisms for regulating plasma potassium (K) levels. Any excess plasma K is probably excreted into urine (Michell 1974; Michell et al., 1988). Urinary K Losses increase in response to increasing K intakes, with faecal losses being largely unaffected (Greene et al., 1983; Karn 1977). Note, however that faecal K losses have been found to be higher than urinary losses at low K (1- 2 g/kg DM) intakes (Karn 1977). Michell (1988) noted and observed rise in faecal K in late gestation in ewes, at high or low sodium intakes. In addition, Delvin and Roberts (1963) reported increased faecal but constant urinary K losses, when low Na was fed to wether lambs. Michell (1985) suggested that increased aldosterone output response to sodium deficit not only increases salivary K levels but also assists in maintaining plasma K by encouraging K excretion.

Vrzgula (1991) and Payne (1987) quoted total body sodium as 1.3 and 1.39 g/kg body weight respectively. The 35 – 45% of body sodium found in bone crystals is relatively unavailable (Field et al., 1968; Michell 1989; Vrzgula 1991) except perhaps for that found on bone surface tissue (Ammerman et al., 1983). Generally bone sodium declines with age (Ammerman et al., 1983), rises in late gestation in ewes but remaining high in early lactation (Field et al., 1968). Michelle (1985) stated that bone sodium metabolism is little understood, and has suggested that bone accretion may be important in sodium excess (Michell 1989).

In sheep fetuses Na and K levels in soft tissues remained relatively unchanged or decreased slightly before parturition (Mc Donald et al., 1979; Grace et al., 1986). There are no studies however, on liver, kidney and brain Na and K levels in newborn lambs or kids (Aitken 1976). Pertaining to piglets and humans, Widdowson and Dickerson (1960) reported significantly higher Na and K levels in liver and kidney tissues in newborn piglets and humans when compared with levels in adults (Table 2). Concerning growing and older animals, Mounib and Evans (1960) compared kidney Na and K levels in lambs (1 year old), adults (4 years old) and aged sheep (6 – 8 years) (Table 2). Older sheep had higher kidney Na but lower K levels when compared with Na and K in growing lambs.

Little is known however, of the physiological Na and K tissue changes from birth to adulthood in sheep and other livestock. The purpose of this study was to compare the changes in the sodium and potassium contents of liver, kidney and brain tissues in newborn lambs with those of growing and adult sheep tissues. The findings from this study might add speculation of the roles of that these two cations at the soft tissue level pertaining to water balance in animals.

2. Materials and Methods

2.1 Ethics Approval

The research protocols for this study were approved by the Veterinary Ethics committee of the Faculty of Medical Sciences, The University of the West Indies

2.2 Farms and management

Tissue samples were taken from 32 newborn lambs, 20 growing lambs (mostly about 6 months), and 25 adult (2-6 yrs) sheep, respectively. Newborn lambs and 6 adult sheep originated from Mon Jaloux livestock farm of Central Trinidad. Six of the growing lambs originated from a large farm of the Central Trinidad via a contract arrangement to slaughter six month animals at the abattoir processing facilities at the Sugar Cane Feeds Centre of the Longdenville area. The large farm was located in the Palmiste area of Central Trinidad. Other sheep tissue samples were obtained from three roadside abattoirs of the Chaguanas and Couva locations of the same area. Figure 1 shows the general locations of all sheep farms.

The farms which tissue samples were taken were situated on variety of clay, sandy clay loams and fine sandy clay loams of Central Trinidad. Sheep were of Barbados Black Belly and West African hair type. Sheep at the Mon Jaloux Livestock farm were kept on a urea-molassess bagasse based feed, to which sodium chloride was added at 0.5 percent. Other sheep from various farms foraged on a wide variety of local grasses, especially bamboo grass (*Paspalum fasciculatum*) para grass (*Brachiaria mutica*) and tapia grass (*Sporobolus indicus*). Sheep were occasionally dewormed at various farms using Oxfendazole at the recommended dosage of 5mg/kg (Synantic, Syntex Agribusiness).

2.3 Sample collection

Blood samples were drawn by venepuncture (16 – 18 mm needle gauge) and collected in acid ashed demineralized tubes. Clotted blood was centrifuged within four hours of collection to remove serum. Liver tissue, whole kidneys and brains were collected from slaughtered animals. All serum and tissue samples were properly labeled and stored at 20◦C.

2.4 Sample analysis

Samples for analysis were taken from the same liver lobe, the kidney cortex mainly (and outer medulla) and the cerebral hemispheres. Oven dried tissue samples (20 – 25 g) were pre-ashed on a hotplate with 50% HNO3, ashed overnight at 550◦ C, and finally solubilized with 10% HCl. Tissue Na and K concentrations were determined on a Dry Matter basis according to Flick et al. (1979) Tissue Na and K concentrations were calculated on a wet weight basis based on their respective dry matters. All mineral determinations were carried out on a Pye Unicam SP2900 Atomic Absorption Spectrophotometer equipped with PU9090 Data Graphics System.

2.5 Statistical Analysis

Standard Error of the Difference (SED) of various tissue N and K means was calculated using the General Linear Model (GML) with Minitab Software 16 (Minitab 16, 2011) (1997 release).

3. Results and Discussion

Table I shows the serum, including tissue sodium (Na) and potassium (K) concentrations found in liver, kidney cortex and brain tissues of newborn, growing and adult sheep.

Serum N and K levels were not significantly different (*P*> 0.05) in new born lambs compared with levels in growing lambs and adult sheep (Table 1).

Table 1. *Tissue Na and K levels (m.eq/w.wt) of newborn, growing and adult sheep of Central Trinidad*

Tissue 1	Na/K	New Born Lambs		Growing Lambs		Adult Sheep		S.E.D	Signf.
		Mean	SD	Mean	SD	Mean	SD	SED	
(n)		(32)		(20)		(25)			
Serum	Na	3178	58	3095	44	3152	35	70	NS
	K	305	6.2	213	4.7	205	3.7	50	NS
Liver	Na[2]	42[a]	7.7	31[b]	6.9	26[b]	3.4	0.71	*P*<0.001
	K[3]	46[a]	12.6	64[b]	6.3	67[b]	8.0	1.21	*P*<0.001
	K/Na	1.1		2.1		2.6			
Kidney	Na	63	7.4	65	8.5	69	10.2	3.00	NS
	K	46	8.1	55	12.3	56	12.0	3.70	NS
	K/Na	0.7		0.9		0.8			
Brain	Na	71[a]	10.4	54[b]	5.0	54[b]	5.0	2.78	*P*<0.001
	K	42[a]	16.5	58[b]	14.3	61[b]	8.5	4.97	*P*<0.001
	K/Na	0.6		1.1		1.1			

[1]Tissue samples taken mainly from the left liver lobe, kidney cortex and cerebral cortex.

[2],[3] levels normally found are 35-39 for Na and 78-86 for K in m.Eq/w.wt (Aitken, 1976)

Higher Na levels but lower K levels were found in liver, (*P*<0.001) and brain (*P*<0.001) tissues of new born lambs compared with levels in growing lambs and adult sheep (Table 1). Only a few animals had concentrations within the expected ranges for liver Na (35-39 m.Eq/w.wt) and liver (78-86 m.Eq/w.wt) as suggested by Aitken (1976) (Table 2). Sixty percent of newborn lambs had liver Na levels above 39 m.Eq/w.wt, whereas 57% of growing and adult sheep had levels below 35 m.Eq/w.wt. Most newborn lambs had liver K levels below 60 m.Eq/w.wt, whereas most growing lambs and adult sheep had levels above this value. Nevertheless, most growing and adult sheep had K: Na ratios about the value expected for ruminants (Aitken, 1976) which contrasted with ratio of unity found in newborn lambs.

Table 2. *Tissue Sodium (Na) and Potassium (k) levels in sheep, goats and piglets*

Description	Element	Liver	Kidney g/kg DM	Brain	Reference
Kids Na Intake					
0.31 g/kg DM	Na	2.9	-	-	Shellner,1972
1.71 g/kg DM	Na	3.4	-	-	
Sheep (1-8 yr)	Na	2.6 – 3.0	8.2 – 8.7	6.5	Mounib and Evans (1960)
	K	12.2-12.2	13.8-14.1	18.2-18.3	
(Abattoir)	Na	-	-	6.1 – 8.9	Hatten (1973)
	K	-	-	9.1 – 15.4	
(1-300wk)	Na	2.6 – 2.7	-	6.7 – 6.	Blaxter and Rook (1956)
	K	9.2 – 10.0	-	14.9 – 15.4	
Pigs (Newborn)	Na	5.4	10.0	7.8	Widdowson and Dickerson (1960)
	K	15.3	17.2	21.8	
(4 weeks)	Na	3.1	6.9	7.4	
	K	13.2	15.5	15.7	
(Adult)	K	11.2	12.4	12.2	
			m-equiv/kg wwt		
Ruminants, Non-ruminants and humans:		35-39	-	-	Aitken (1976)
	Na	78-86	-	-	
	K	63.0	100.2	-	

Foetal lamb (143 d)	Na	75.0	51.5	-	Grace et al; 1986
	K	33.2	65.8	-	
Sheep (1 year)	Na	83.2	71.9	-	Mounib and Evans (1960)
	K	34.5	69.6	-	
(4 years)	Na	78.9	71.5	-	
	K	35.5	70.8	-	
(6- 8 yr)	Na	80.1	67.9	-	

Mean brain Na concentrations in newborn lambs expressed as m.Eq/DM was 507 compared with considerable lower than means of 256 and 252 found in growing lambs and adult sheep. Most newborn lambs had brain Na above the upper limit of the range 265-388 reported for adult sheep by Hatten (1973). However, most growing and adult sheep had levels within this range. Although there are no reports of liver Na concentrations in newborn lambs, studies in near-term fetal lambs (Grace et al., 1986) (Table 2) newborn babies, adult sheep (Aitken, 1976) (Table 2) and adult humans (Widdowson et al., 1960) (Table 2), suggest that there is a reversal of Na and K levels as sheep mature.

Preliminary indications from this study implied that not only was there a reversal of Na and K levels in liver but also in brain tissues of newborn compared with growing and adult sheep. Similar findings have been reported in human foetuses, newborn babies and adult humans (Widdowson et al., 1960). The tissue K concentrations reported in this study is about 70% of levels reported for tissues in beef cattle (Anonymous 1998). The liver and kidney Na concentrations were at the lower limit of ranges reported for the European Bison and somewhat similar to those reported for beef cattle (Kośla et al., 2015; Anke et al., 2006).

4. Conclusion

Preliminary indications from this study implied that not only was there a reversal of Na and K levels in liver but also in brain tissues of newborn compared with growing and adult sheep.

Acknowledgements

Special thanks are due to Mr. Errol Boodoo and Mr. Keith Tambir of the Abattior facilities of the Sugar Cane Feeds Centre who assisted in the various blood and tissue collections. We are also thankful of the local butchers who assisted in a similar manner at the three roadside abattoirs. Special thanks are also due to Mr. Seemungal Deosaran and Mrs. Radica Seerattan-Persad for assisting in the various tissue laboratory analyses.

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