DOI: 10.7589/2014-07-182

Journal of Wildlife Diseases, 51(4), 2015, pp. 876–879

Fructosamine: An Alternative to Serum Glucose Measurement in White-tailed Deer (*Odocoileus virginianus*)

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ABSTRACT: We determined the relationship between fructosamine and serum glucose in free-ranging white-tailed deer (*Odocoileus virginianus*) harvested during two seasonally stressful periods for deer in coastal North Carolina, US: July 2008 represented the post-parturition and lactation period, and March 2009 represented the late winter and pre–green-up period. Serum glucose and fructosamine concentrations were similar between time periods but were uncorrelated within each season. However, when serum glucose was separated into high and low categories based on the median blood glucose score within each time period, we detected statistically significant differences between July and March for serum glucose. Fructosamine was more stable than serum glucose for evaluating the white-tailed deer physiologic condition.

Key words: Blood, fructosamine, nutritional condition, *Odocoileus virginianus*, serum glucose, white-tailed deer.

Serum glucose is often included in blood chemistry profiles as a metabolic indicator of physiologic condition (Jenks et al. 1991; DelGiudice et al. 1992; Jenks and Leslie 2003) or nutritional status and health in wildlife (Franzmann and LeResche 1978; Nieminen 1980; Hollmén et al. 2001). Additionally, serum glucose is an important index of acute and repeated stress (Franzmann et al. 1975; Armario et al. 1990; Stringer et al. 2011). However, the use of serum glucose as an index to nutritional status, body condition, and stress may be biased in animals chemically immobilized or restrained (Mautz et al. 1980; Kock et al. 1987; DelGiudice et al. 1988; Arnemo and Ranheim 1999) and may not accurately represent the condition of free-ranging animals.

Glucose binds to proteins in a nonenzymatic irreversible reaction (i.e., glycosylation), resulting in a glycosylated protein (i.e., fructosamine; Armbruster 1987; Vasan et al. 1996). One serum glucose measurement reflects the glucose concentration at the time of collection (Raju and Nageshwara Rao 2005). Also, glucose measurements are affected by stress or excitement (Verme and Ullrey 1984; Marca et al. 2000; Loste and Marca 2001; Bennett 2002), time between collection and the assay (Turchiano et al. 2013), and delays in serum separation (Zhang et al. 1998). Conversely, fructosamine concentrations are believed to be proportional to average glucose concentrations over a 2- to 3-wk period (Armbruster 1987) and may be an indicator of the average glucose concentration to which serum proteins were exposed over their life span (Kawamoto et al. 1992; Raju and Nageshwara Rao 2005). Hence, fructosamine should be more stable than glucose and should be a stable estimator of long-term glucose status and physiologic condition.

Fructosamine has been extensively used to monitor diabetes in companion animals (Jensen 1992, 1994; Marca et al. 2000; Loste and Marca 2001; Bennett 2002; Willems et al. 2012) and captive animals (Murphy et al. 1997; Coppo 2001; Fleming et al. 2006). However, little research has been conducted on fructosamine concentrations with free-ranging ungulates. We

compared serum glucose and fructosamine in free-ranging white-tailed deer (*Odocoileus virginianus*) harvested during the two most stressful periods for deer in coastal North Carolina, US, and assessed the appropriateness of fructosamine as a metric for evaluating long-term serum glucose status and physiologic condition in white-tailed deer.

In July 2008 and March 2009, we headshot deer at night by using high-powered rifles: July 2008 represented the postparturition and lactation period, and March 2009 represented the late winter and pre–green-up period (Chitwood et al. 2013). Within minutes of collapse, we collected blood via cardiac puncture and stored samples on ice until centrifuged (<6 h after collection). After separation, we froze serum until processed by Antech Diagnostics (Melville, New York, USA). Glucose concentrations were determined by using an Olympus AU5400 analyzer (Olympus, Upper Saucon, Pennsylvania, USA), and fructosamine was determined with a colorimetric assay (Johnson et al. 1983; Baker et al. 1985). We used *t*-tests to compare glucose and fructosamine concentrations between time periods and Pearson correlations to compare relationships within time periods. For all analyses, we used $\alpha=0.05$ for statistical significance and analyzed results by using SYSTAT (Systat Software, Inc., San Jose, California, USA). Deer collection was approved by the North Carolina Wildlife Resources Commission and the North Carolina State University Institutional Animal Care and Use Committee (08-082-O).

We collected 30 female deer in July 2008 and March 2009 (60 deer total). Serum samples were obtained for all deer, except one in March 2009. In July, serum glucose and fructosamine averaged 194±14 (SE) mg/dL and 242±5 μmol/L, respectively. In March, serum glucose and fructosamine averaged 200±17 mg/dL and 244±4 μmol/L, respectively. Serum glucose ($t=-0.300$; df=57; $P=0.765$) and fructosamine ($t=-0.266$; df=57; $P=0.791$) concentrations were similar between time periods but uncorrelated within season (July=0.394; March=0.277).

Following Jenks et al. (1991), we separated deer into high and low serum glucose categories based on the median blood glucose score within each period (July=194.5 mg/dL; March=185 mg/dL). In July and March, there was a significant difference between the high and low categories in serum glucose ($t=7.276$, df=28, and $P<0.001$; $t=7.215$, df=27, and $P<0.001$) but not fructosamine ($t=1.552$, df=28, and $P=0.132$; $t=-0.036$, df=27, and $P=0.972$), indicating that fructosamine was more stable than serum glucose for evaluating white-tailed deer physiologic condition.

Regardless of time period, our serum glucose and fructosamine measurements were similar to published values (serum glucose: 60–320 mg/dL; fructosamine: 197–362 μmol/L) for white-tailed deer and captive species (Jenks et al. 1991; Murphy et al. 1997; Coppo 2001; Fleming et al. 2006; Ditchkoff 2011). Although we believe our methodology likely reduced any stress-related changes in blood parameters (Blankenship and Varner 1977; Sams et al. 1993), we detected significant differences in serum glucose within period when separated into high and low categories, which was likely due to acute changes from stress or excitement prior to collection (Verme and Ullrey 1984; Marca et al. 2000) rather than long-term seasonal changes (Wade and Warren 1984). Conversely, fructosamine was stable between and within time periods and not affected by acute glycemic changes or circadian variation (Jensen et al. 1993; Marca et al. 2000).

Similar to Jenks et al. (1991), the significant variability in serum glucose concentrations between the high and low categories and lack of correlation with fructosamine in both periods indicated that glucose is unusable in assessing the glycemic status of deer. Conversely, fructosamine was more stable than serum glucose within and between time periods.

We established baseline fructosamine values for free-ranging female white-tailed deer during the two most stressful periods in the southeastern US. More specifically, we demonstrated that fructosamine is an appropriate metric for evaluating long-term serum glucose status and evaluating the physiologic condition for white-tailed deer.

Funding was provided by the North Carolina State Natural Resources Foundation, the North Carolina State University (NCSU) Department of Forestry and Environmental Resources, and the NCSU Fisheries, Wildlife, and Conservation Biology Program. We thank the North Carolina Wildlife Resources Commission for help with deer collections, J. H. Harrelson and A. Partin for help in the field, and the undergraduate and graduate students of the NCSU Fisheries, Wildlife, and Conservation Biology Program for field assistance.

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Submitted for publication 28 July 2014.
Accepted 24 January 2015.