Review article

Some Metabolic Profile Markers in Goats

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Doi: 10.5281/zenodo.7486065

Abstract

Herd health control programs in large- or small-scale goat farms can both positively affect the future of the farm and increase the profit to be obtained. For this reason, pregnancy, birth and postpartum processes, in which intense physiological and biochemical events occur, should be followed closely. Within the framework of the herd health control program, biochemical activities in the processes related to the metabolic profile test application are monitored and attempts are made to eliminate the metabolic problems or deficiencies that may occur. In this review, some metabolic profile test markers in goats were mentioned.

Keywords: Glucose, goats, metabolic profile, pregnancy, transition period

Introduction

Many metabolic and physiological events occur in domestic animals in the pre-pregnancy, pregnancy and post-pregnancy period. Although there are some differences between races, changes in some biochemical parameters can be observed in different physiological processes (Liesegang et al., 2007). Pregnancy and lactation periods are metabolically stressful periods. Certain hematological and biochemical changes may occur in low milk producing ruminants kept in natural pastures and sheep and goats raised on certain diets (Eşki et al., 2015; Harwood & Mueller, 2018).

Goats have started to receive increasing economic interest worldwide due to their rapid adaptation to the environment and pastures. This intense interest aims to produce high quality products with special emphasis on animal production, animal health and animal welfare. The adoption of intensive husbandry methods in goats for higher milk yields may increase the incidence of prenatal metabolic disorders (Rubino et al., 1995). In this process, the results to be obtained by measuring enzymes, proteins and metabolic biochemical parameters can be helpful descriptive tools for some diseases (Kaneko et al., 2008). This forms the basis of metabolic profiling tests, which help to predict and therefore prevent the occurrence of various prenatal metabolic disorders. Pregnancy and lactation periods are physiological stages thought to cause metabolic stress (Drackley, 1999). During this period, ruminants may experience oxidative stress (Castillo et al., 2006), so pre/postnatal metabolic diseases may occur (Miller et al., 1993).

In the last week of pregnancy, metabolic demands shift from the need in fetal and uterine metabolism to higher milk production (Vazquez-Añon et al., 1994). With the decrease in feed intake in the last weeks of pregnancy, negative energy balance (NEB) may occur (Bertics et al., 1992; Adewuyi et al., 2005). High non-esterified fatty acids (NEFA) serum concentration indicates a higher fat mobilization rate, while beta hydroxy butyric acid (BHBA) reflects the integrity of lipid oxidation (Leblanc, 2010).

Metabolic changes can occur even in low-yielding goats if animals are underfed or irregularly fed during periods that require a high nutrient supply, such as the prenatal and postnatal period. Serum concentrations of free fatty acids, triglycerides, cholesterol, urea and creatinine may be higher in sheep and goats with pregnancy toxemia and multiple pregnancies compared to sheep and goats without pregnancy toxemia (Kolb & Kaskous, 2004; Kaçar et al., 2010; McClure et al., 2014).

The aim of this review is to give information about some metabolic profile test parameters that are measured in goats during the transition period, before pregnancy or during lactation.

Some metabolic profile markers in goats

Glucose

Glucose (GLU) is a six-carbon aldose sugar and is involved in energy metabolism. In ruminants, carbohydrate digestion begins in the rumen. Anaerobic microorganisms digest polysaccharides such as starch, sugar and cellulose to form carbon dioxide, water, heat and essential fatty acids. Essential fatty acids are absorbed by the rumen and used for energy needs. The energy requirement is largely provided by glucose (Ergün et al., 2001). The blood glucose concentration differs according to the physiological period and the amount in the diet (Moallem et al., 2012). As the energy requirement increases throughout the pregnancy, there is a serious need for energy due to rapid fetal development in the last stages of pregnancy (Voicu et al., 1993; Sguizzato et al., 2020). In fact, serum glucose concentrations were found to be statistically different in singleton pregnancy and triplet and quadruplet pregnancy (Moallem et al., 2012). In addition, more energy is needed after birth, and even the newborn has to store glucose in order to meet its energy (Voicu et al., 1993; Sguizzato et al., 2020). Newborns need about 30-40 g glucose in their first day (Marteniuk & Herdt, 1988; Browning & Correa, 2008). Serum glucose concentration in goats has been reported to be between 50–75 mg/dL (Kaneko et al., 2008) or 43-72 mg/dL (Harwood & Mueller, 2018; Akyüz et al., 2020b).

Non-esterified Fatty Acids

In ruminants, the fats stored in the body are mobilized for the increased energy needs in early pregnancy and lactation. Especially goats under heat stress reduce their feed intake to reduce metabolic rate. After this event, lipid mobilization may increase, and the level of non-esterified fatty acids (NEFA) may increase (Gupta & Mondal, 2021). Fatty acids in the lipid tissue enter the blood circulation as NEFA and come to the liver from there and are used for gluconeogenesis and glucose synthesis. Thus, a positive correlation is established between serum NEFA concentration and negative energy balance (Kaneko et al., 2008). Adaptation to NEB in high dairy goats is primarily regulated by glucose, NEFA and ketone bodies (Şentürk, 2017). Again, it is one of the best parameters to monitor hyperketonemia between days 3 and 16 of lactation in dairy goats (Zamuner et al., 2020b, 2020a).

Beta Hydroxy Butyric Acid

Beta hydroxy butyric acid (BHBA) is an intermediate of fatty acid oxidation and good laboratory evidence demonstrating the presence of NEB. Measurements are made within the framework of herd control programs, especially in dairy farms (Duffield, 2006; Şentürk, 2017). Along with BHBA, the most well-known ketone substances are acetoacetic acid and acetone. Disruptions in the energy balance cause an increase in fat oxidation and the production of ketone bodies increases. Since BHBA is more stable than other ketone substances, it is more preferred in clinical practice in terms of measurement (Duffield, 2006). It is very useful to measure pregnancy toxemia, which is a metabolic problem that can occur in small ruminants, especially in multiple pregnancies (Ramin et al., 2005; Harmeyer & Schlumbohm, 2006; Marutsova & Binev, 2017). In goats, BHBA can vary between 0–1.2 mmol/L (Harwood & Mueller, 2018).

Triglycerides

Triglycerides (TG) are glycerol esters of fatty acids, which are the lipid components given in the diet in ruminants (Karagül et al., 2000). The liquid form of triglycerides at room temperature, which can be called natural fat, is vegetable oil, and the solid form is animal fat. TG is produced in the liver as a result of its esterification with nutrients absorbed in the intestine. Determination of TG concentration is useful in conditions such as hyperlipidemia and hypercholesterolemia (Piccione et al., 2009; Akkaya, 2017; Akkaya et al., 2020). TG concentration in small ruminants is 63-92 mg/dL (Piccione et al., 2009; Elitok, 2012; Jimoh et al., 2019) or 0.16-0.64 mmol/L (Eşki et al., 2015; Allaoua & Mahdi, 2018; Cappai et al., 2019; Antunović et al., 2020; Ölmez et al., 2020).

Cholesterol

Cholesterol (CHOL) consists of a phenanthrene core to which a cyclopentane ring is attached and has an eight-carbon side chain attached to the cyclopentane ring. CHOL is found only in animals and not in plants or microorganisms. CHOL is a precursor of steroid hormones, vitamin D, bile acids, and is a component of cell membranes and bile micelles. CHOL can be obtained or synthesized from diet containing animal products. The main synthetic and catabolic organ for CHOL is the liver. Steroidogenic endocrine organs (adrenal cortex, testis, ovary, placenta) can synthesize small amounts of CHOL; however, these organs use hepatically synthesized CHOL for most of their steroid synthesis. Pure CHOL and its esters are insoluble waxy white solids and are transported in plasma as a part of lipoproteins (Karagül et al., 2000; Kaneko et al., 2008). CHOL is transported in the living body in three ways, of which 60-70% is low-density lipoprotein (LDL), 20-35% is high-density lipoprotein (HDL), and 5-12% is the very low-density lipoprotein (VLDL) fraction (Turgut, 2000). The serum/plasma concentration of CHOL in goats can range from 2.07-3.37 mmol/L (Kaneko et al., 2008) or 80-130 mg/dL (Pugh & Baird, 2012; Kuru et al., 2020).

Aspartate Amino Transferase

Aspartate aminotransferase (AST) is found in high concentrations in various tissues, including skeletal-cardiac muscles, erythrocytes, kidneys, and liver. This enzyme is a nonspecific indicator of tissue damage. The half-life of circulating AST is relatively long (more than 2 days in large animals). Extensive muscle necrosis may have much higher AST elevations than severe liver necrosis. AST is relatively stable at room temperature but can alter hemolysis or lipemia assay results (Stokol & Erb, 1998; Karagül et al., 2000). In summary, serum AST determinations are part of many biochemical profiles due to their relatively high sensitivity for hepatocyte damage, myocyte damage, and stability in serum. However, serum AST activity lacks significant specificity compared to tissue-specific enzymes such as sorbitol dehydrogenase and glutamate dehydrogenase for detection of hepatocyte damage and creatine kinase for detection of myocyte damage (Kaneko et al., 2008). AST concentration in goats can vary between 0–300 IU/L (Harwood & Mueller, 2018) or 167-513 IU/L (Pugh & Baird, 2012).

Albumin

Among the total proteins, it is one of the most important and most stored proteins in the body (Başoğlu & Sevinç, 2004). The amino acid sequence of albumin (ALB) consists of a single polypeptide chain (Nicholson et al., 2000; Mazzaferro et al., 2002). In other words, it is a water-soluble protein that does not contain carbohydrates but contains lipids (Krajničáková et al., 2003; Balikci et al., 2007). The most important function of ALB in the body is binding and carrier (Başoğlu & Sevinç, 2004). In addition, albumin synthesis may differ according to nutrition and health status (Mazzaferro et al., 2002). However, albumin is a negative acute phase protein that can be measured in serum and urine, and its serum concentrations may decrease in cases of inflammation (Tothova et al., 2014; Kuru et al., 2015). ALB reference values in goats have been reported to vary between 27.0–39.0 g/L (Kaneko et al., 2008; Akyüz et al., 2020a).

Total Protein

Total proteins (TP), also called plasma proteins, are found up to 7 g in 100 g of blood (Başoğlu & Sevinç, 2004). There are over 300 total proteins in living plasma. These proteins function in different functions in the body. While some of them collectively undertake the nutritional function, other parts regulate the colloid osmotic pressure and acid-base balance (Karagül et al., 2000). There are certain reasons why total proteins, which are very important in growth and development, are higher or lower than the reference values. The most important reason for its high concentration is dehydration and hyperimmunoglobulinemia. The reason for its low concentration is chronic infections, pregnancy, gastroenteropathy, edema, traumas, excess acid in the body, nutritional disorders and liver diseases (Mbassa & Poulsen, 1991; Balikci et al., 2007; Kaneko et al., 2008). In goats, the total protein concentration may vary, especially in the pre-pregnancy, early-late pregnancy, early-late lactation and dry periods (Mbassa & Poulsen, 1991). The TP reference value in goats can vary between 6.2–7.9 g/dL (Jackson & Cockcroft, 2002).

Blood Urea Nitrogen

The purpose of animal husbandry is to convert carbohydrates and proteins in animal feed into food sources for humans; however, only 5% to 30% of the nitrogen in the diet is used and the rest is excreted by the animals. Since plasma blood urea nitrogen (BUN) concentration is an indicator of protein status, it can help fine-tune diets or identify problems with a feeding program (Kohn et al., 2005). BUN is an organic molecule of carbamide and urea, represented by the formula CO(NH2)2. Bicarbonate (HCO3), which is the product of the metabolism of ammonia (NH3) and carbon dioxide (CO_2) that is formed during the fermentation of amino acids, is removed from the living thing to be converted to urea, which is a non-toxic product (Meijer et al., 1990). In the case of the ornithine cycle, the liver is the most important organ in the passage of urea nitrogen into the blood. In addition, not all of the NH_3 that comes to the liver is converted to urea. In ruminants, urea is the most important end product of blood nitrogen metabolism (Atkinson & Bourke, 1984; Kaneko et al., 2008). Serum/plasma urea nitrogen concentration in goats can vary between 10-20 mg/dL (Smith, 2015).

Creatinine

Creatinine (CREA) is a small molecule produced by the breakdown of creatine and creatine-phosphate, an energy-storing molecule found mainly in skeletal muscles. CREA is synthesized from the amino acids glycine, arginine and methionine, which is the last step that occurs in the liver. It is then taken up by the muscles, where it is reversibly phosphorylated by creatine-kinase and converted to creatine-phosphate. Skeletal muscles contain approximately 95% of total body creatine and creatine-phosphate (Wyss & Kaddurah-Daouk, 2000; Kaneko et al., 2008; Santos et al., 2017). CREA mainly circulates in plasma in free form and is distributed in the water compartments of the whole body. CREA secretion increase with active transport in the proximal tubule in renal failure is not similar in sheep, rabbits, pigs and goats (Kaneko et al., 2008). However, serum CREA, like BUN, is not a very sensitive or early indicator of changes in kidney function. Changes in renal blood flow due to reductions in circulating fluid volume (hypovolemia) cause an increase in serum CREA and BUN; this can be considered as prerenal azotemia. Prerenal azotemia is usually seen in animals with dehydration and sodium (Na)-containing fluid loss (Kaneko et al., 2008; Smith, 2015). In ruminants, CREA is a more reliable indicator of renal failure than BUN. Prerenal azotemia decreased renal perfusion, hypovolemia, congestive heart failure, acute-chronic kidney failure, urolithiasis, kidney stones, ureteral stones, urinary bladder ruptures can be counted as common causes of increased CREA concentration. Uncommon causes are perirenal abscess, kidney carcinoma, poisonings, heavy metal poisoning, non-steroidal anti-inflammatory drug poisoning, and aminoglycoside poisoning (Smith, 2015). The mean CREA value in goats was 0.6–1.6 mg/dL (Jackson & Cockcroft, 2002) or 1.0-1.82 mg/dL (Pugh & Baird, 2012).

Calcium

Calcium (Ca) is the most abundant element in the body as a macro mineral. It constitutes 1-2% of the total weight of the body, 99% of the total calcium in the living is located in the bones and teeth, while the remaining 1% is located in the soft tissue and extracellular fluid. Elements such as iron (Fe), aluminum (Al) and magnesium (Mg) form insoluble phosphate salts, and fatty acids form insoluble calcium soaps, reducing the absorption rate of calcium. Vitamin D is needed for the absorption of calcium from the small intestine by active transport mechanism. Because it plays a role in the binding of calcium with protein (Ergün et al., 2001). The unabsorbed parts of calcium are excreted from the body through sweat, feces and urine (Kohler et al., 2013). In general, the normal values of calcium in domestic animals are between 9-12 mg/dL (Karagül et al., 2000). Serum Ca concentration in goats ranges from 8.9-11.7 mg/dL (Pugh & Baird, 2012) or 2.3–2.9 mmol/L (Harwood & Mueller, 2018).

Phosphorus

Phosphate in the mammalian body is predominantly (90%) found as hydroxyapatite in the mineralized bone matrix, with most of the remaining 10% found intracellularly in soft tissues (Rosol & Capen, 1996). As a mineral in the bone tissue in the body, it has taken the second place after calcium with a rate of 85%. The remaining 20% is found organically in soft (muscle) tissues (Ergün et al., 2001). It is an essential element that takes on important tasks after calcium in the body. It has important intracellular functions such as neurological functions, electrolyte transport and muscle contraction (Kargin et al., 2004). If the required amount of phosphorus (P) is not present in the diet, P degradation occurs from the bones in order to optimize the plasma concentration. Since P withdrawal from bones is more severe than calcium withdrawal, P deficiency symptoms are seen earlier than calcium deficiency symptoms in the body (Ergün et al., 2001). It is excreted from the body in feces (30%) in herbivores, in high amounts in urine in carnivores, and in the form of inorganic phosphate (Goff, 2000; Kargin et al., 2004). Serum phosphate concentration in goats varies between 4.2-9.1 mg/dL (Kaneko et al., 2008).

Magnesium

Magnesium is an indispensable nutrient for animals. Green plants are an excellent source of Mg for animals due to the presence of Mg^{2+} in chlorophyll. Mg is the fourth most common cation in the body [after Ca, Na, and potassium (K)]. The body of pets contains 0.05% Mg; 60% of these are found in the skeleton, 38% in the soft tissue, and between 1% and 2% in the extracellular component. Mg metabolism has been most studied in ruminants because clinical disorders due to Mg deficiency are common in this species (Rosol & Capen, 1996). One third of the magnesium in the blood serum is bound with proteins (Ergün et al., 2001). Magnesium, which is required for the activation of more than one enzyme, is primarily required for the transfer and hydrolysis of phosphate groups, as well as for important functions such as lipid, amino acid, nucleic acid synthesis and glucose use required for ATP and muscle contraction (Kaneko et al., 2008). Mg is essentially an intracellular cation and acts as an activator or a catalyst for more than 300 enzymes in the body, including phosphatases and ATP-containing enzymes. All reactions using ATP require Mg+2. The effect of magnesium extends to all major anabolic and catabolic processes. Therefore, Mg plays an important role in muscle contraction, protein, fat and carbohydrate metabolism, oxidative phosphorylation by methyl group transfer, stabilization of membranes with functional properties, cell division and immune responses (Rosol & Capen, 1996). Along with Mg, P and Ca, it is important in bone development. An average of 30-50% of Mg taken with the diet is absorbed in the small intestine. It is excreted from the body in two ways with urine and feces (Ergün et al., 2001). The serum magnesium concentration ranges from 1.5 to 5 mg/dL (0.8 to 2.1 mmol/L), depending on the species (Rosol & Capen, 1996). Serum Mg concentration in goats is 2.8-3.6 mg/dL (Smith, 2015), 0.31–1.48 mmol/L (Kaneko et al., 2008), or 0.8–1.3 mmol/L (Harwood & Mueller, 2018).

Conclusion

As a result, goats can adapt to most pasture conditions around the world, but their numbers do not increase in parallel with population growth in Turkey. Farms, including intensive enterprises, have been established in recent years. Since the aim is to achieve high efficiency in such enterprises, it is necessary to follow the metabolic changes of pregnancy and post-pregnancy process, especially where intense physiological activities are experienced. The most important reflection of the desire to obtain high productivity in goats in the pre-pregnancy and post-pregnancy processes has been metabolic diseases. Therefore, measurement of metabolic profile markers in related processes is important for herd management. Metabolic stress may occur during pregnancy and lactation, especially in high milk yielding goats. In addition, grazing on poor quality pastures in the prepartum period or feeding with unbalanced rations predisposes to metabolic diseases. Metabolic profile testing can be useful to reveal the presence or risk of catching diseases, especially in order to prevent economic losses.

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