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Review

Assessing the nutritional status of beef cattle: current practices and future prospects

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Accurate determination of nutritional and health status of animals is invaluable in modern animal agriculture. Body weights and body condition scoring are the commonly used methods of assessing nutritional status of animals. This paper discusses drawbacks these methods have and highlights the benefits for using blood metabolites in assessing nutritional status of beef cattle. Blood metabolite levels indicate the extent of metabolism of energy, proteins and other nutrients in animals. Glucose, cholesterol, non-esterified fatty acids, protein, urea, creatinine, albumin, globulin, minerals, liver enzymes and haematology can be used objectively, reliably and routinely to assess the nutritional status of cattle. In Southern Africa, the use of these metabolites is rare due to lack of equipment for blood analysis and the high cost of analyzing the blood parameters. However, use of high value Nguni cattle in Southern Africa requires the use of blood parameters to accurately assess their nutritional status. Several factors, such as physiological status of an animal, breed, nutrition, season and age affect levels of blood metabolites. Combining body weights, body condition scores and blood metabolites increase accuracy of assessing the nutritional state and welfare of beef cattle.

Key words: Body condition scoring, blood metabolites, nutritional status, cattle.

INTRODUCTION

Although cattle provide diverse functions to farmers in Africa (Scoones and Graham, 1994), their productivity is generally low. Cattle provide draught animal power, social and cultural functions as well as serving as security and risk reduction in rural households (Corbet et al., 2005; Anderson, 2003). Cattle, therefore, contribute to subsistence farming and enhance the sustainability of smallholder farming systems. Peak daily milk yield is approximately 5 kg and most animals lose body weight during winter. Calving intervals are way above the recommended 12 to 13 months (Chimonyo et al., 2000) and calf mortality rates are high. There are various factors that reduce cattle productivity, chief of which is the low veld quality during the dry season and the general poor health management practices (Berry et al., 2006). It is possible that undernutrition is common during this period (Agenas et al., 2006).

Indigenous cattle breeds are being threatened with disappearance largely due to indiscriminate crossbreeding (Otto et al., 2000) and institutional policies that promote the use of imported beef cattle breeds in rural areas. Efforts are now under way to repopulate the rural areas of South Africa with the indigenous Nguni cattle. Hereford, Aberdeen Angus and Sentimental breeds are being distributed in Southern Africa. Since apartheid far-

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Abbreviations: UFH, University of Fort Hare; NEFA, Non-esterified fatty acids;
VLDL, very low density lipoproteins; BHB, β–hydroxybutyrate; BUN, blood urea nitrogen; ERDP, effective rumen degradable protein; PCV, packed cell volume; AST, Aspartate aminotransferases; CK, creatinine kinase; ALT, Alanine transferase.

mers have no choice and look upon indigenous breeds as inferior. The University of Fort Hare (UFH) Nguni Cattle Project aims not only to increase the number of the indigenous Nguni cattle in the communal areas, but also to see through identification and creation of niche markets. The UFH model aims to grade up the existing cattle population in the communal areas by eliminating all non-Nguni bulls within a community. The Nguni is increasingly attracting international interest, mainly due to their resistance to ticks and tick-borne diseases, high reproductive performance and good walking and foraging ability (Strydom et al., 2001; Muchenje et al., 2007). For efficient production and for improving their marketability, the nutritional status of the introduced animals needs to be closely monitored (Chimonyo et al., 2002).

More accurate assessment of nutritional states of cattle can be made using blood metabolite concentrations than from assessment of body weights or condition scores alone. Serum concentrations of metabolites such as glucose, cholesterol, Non-esterified fatty acids, blood urea nitrogen, creatinine, total proteins, albumin, globulin and minerals are commonly used to assess the nutritional status of cattle. Use of blood metabolites has been applied mainly in dairy cows (Whitaker et al*.,* 1999) due to the intensive production systems used and their high susceptibility to metabolic disorders. Extensive farming practices in beef production make it difficult to conduct routine sampling from these animals even though beef cattle are also susceptible to metabolic disorders such as grass tetany a condition resulting from calcium and magnesium deficiency. Information on the effects that variations in breed, season and physiological state of beef animals may have on serum concentrations of metabolites is inadequate. Moreover, blood metabolite levels which form the basis of creating reference values for assessing nutritional status of animals, have not yet been established for the Nguni cattle. Determination of the levels of blood metabolites for Nguni cattle will allow for comparison with imported breeds, increasing an understanding of adaptability of cattle to local production conditions (Grunwaldt et al., 2005) and formulating ways to improve their production (Otto et al., 2000). Determination of blood metabolite concentrations for Nguni cattle will provide information that serves as the basis for the diagnosis, treatment, and prognosis of diseases that could affect indigenous cattle breed (Yokus and Cakir, 2006). In this paper, we review the methods used for the accurate and reliable assessment of the nutritional status of cattle.

Traditional methods of assessing nutritional status of cattle

Determination of the nutritional status of cattle is useful in quantifying the extent to which cattle are affected by nutriation, disease or other environmental factors, especially where seasonal fluctuations in the quantity and quality of forages occur, as is common in dry tropical and subtropical areas. Body weights and body condition scoring are the traditional methods used to assess nutritional status of animals though they have several limitations or drawbacks.

Body weights and its limitations

Typically, growth is measured as an increase in body weight and it includes not only cell multiplication (hyperplasia) but also cell enlargement (hypertrophy) and incorporation of specific components from the environment (for example, apatite deposition) (Flier and Maratos-Flier, 2000). Growth can be monitored by using body weights. Body weights are commonly used because it is easier and quicker to perform, not much expertise is required and that it is not tedious to perform.

Body weights are commonly used for monitoring nutritional status and growth of animals (Chimonyo et al., 2000). However, the body weight of an animal *per se* does not reflect its nutritional status (Oulun, 2005). Animals with large frames may have higher body weights with low level of body reserves than small framed ones with abundant reserves. Changes in body weight, therefore, become more informative than body weights per se. Large variations in body weight may occur as a result of changes in gut fill and bladder fill, pregnancy and parturition (National Research Council, 1996). Moreover, weight changes may reflect tissue hydration rather than significant alterations in body protein or fat content (National Research Council, 1996). To minimize the effect of frame size of the animal, body weight measurements should be collected regularly, often on a monthly basis. The influence of gut fill on body weight measurements can be reduced by weighing the animals at a consistent time of day. This requirement is difficult to meet, since animals are usually presented to the handling facilities at different times. Calibration of weighing scales was also difficult.

Body condition scoring and its limitations

Body condition scoring describes the systematic process of assessing the degree of fatness of an animal (Nicholson and Sayers, 1987). The score reflects the plane of nutrition on which an animal has been exposed over a reasonable length of time (Stuth et al., 1998). The loin, ribs, tail head, brisket, flank, vulva and/or rectum and udder are the important parts of the body used in determining the score. Physiologically, the proportion of protein and water of the animal's bodyweight decrease as it gains body condition (National Research Council, 1996). Several authors have documented association between body condition scoring and fertility (Buckley et al., 2003) and health (Roche and Berry, 2006).

Table 1. Description of condition scores on a 9 -point scale.

Score	Condition	Appearance
1	Emaciated	Shoulder, rib and back are visible
2	Very thin	Some muscle, no fat deposits
3	Thin	Some fat deposits, ribs visible
4	Borderline	Fore ribs not noticeable
5	Moderate	12^{th} and 13^{th} ribs not visible
6	Good	Ribs covered, sponginess
7	Very good	Abundant fat on tail head
8	Fat	Fat cover thick and spongy
9	Obese	Extremely fat throughout

Source: Nicholson and Butterworth (1986).

Initially, body condition scoring was conducted on a 5 -point scale (Nicholson and Sayers, 1987). However, the 5 -point scale has been deemed inappropriate for tropical breeds of cattle as it does not cover a wide enough range of animals in poor conditions that are commonly found in rural areas. In addition, it has been reported to be inappropriate for small-framed animals that predominate in the tropics. The 5 -point scale is, however, quite popularly used by dairy producers. The 9 -point scale is recommended for tropical cattle, such as *Bos indicus* (Nicholson and Butterworth, 1986). As indicated in Table 1, the scores range from one (severely emaciated) to nine (obese). Body condition scoring is easy to apply and has been extremely used as a management tool largely in the dairy sector. Body condition scoring is least reliable for calves and weaners, as they tend not to have heavy fat deposits. Despite the reported repeatability estimates in experienced assessors (Ferguson et al., 1994), the general subjective nature of body condition scoring makes it difficult for inexperienced herd managers, to correctly score the animals. Unlike body weight measurements, the automation of body condition scoring has, to date, been unsuccessful (Berry et al., 2006). More accurate means of determining nutritional status of animals should be adopted.

Although there is a general consensus that the genes that influence body condition scores and body weights are either closely linked or could have pleiotropic effects on each other, Berry et al. (2006) observed a low correlation coefficient between body weight and condition scores. There is need therefore to develop other tools to aid management of beef cattle (Berry et al., 2006). An objective indicator of nutritional status, which could be reliably and routinely used to aid management of cattle in rural areas, is to determine levels of nutritionally related blood metabolites (Oulun, 2005; Agenas et al., 2006).

Use of blood metabolites to complement traditional methods

Blood metabolite concentrations represent an integrated index of the adequacy of nutrient supply in relation to nutrient utilization of cattle (Chester-Jones et al., 1990). They give an immediate indication of an animal's nutriational status at that point in time (Pambu-Gollah et al., 2000). In the dairy industry, the use of metabolic profiles for assessing the nutritional and health status of cows is widespread (Doornenbal et al., 1988; Grunwaldt et al., 2005). Use of such metabolites in the management of beef cattle is still uncommon. Reference values for Nguni cattle are not available, which makes it difficult to determine their nutritional status. There is, therefore, a need to develop reference values for such breeds for adequate characterization and to aid in their management. The major blood constituents that can be routinely assayed include haematology parameters, glucose, non-esterified fatty acids, β-hydroxyl-butyrate, cholesterol, total proteins, albumin, urea and minerals.

Blood metabolites related to energy metabolism

Blood glucose, β-hydroxy butyrate and non-esterified fatty acids are the most common metabolites used to assess the energy status of cattle. Blood glucose has a moderate diagnostic value in the assessment of nutritional status of cattle as it varies moderately in blood. Insufficient nutrient intake can reduce circulatory glucose and cholesterol levels. In conditions of undernutrition, the blood levels of propionate and other precursors derived from the diet decreases thus causing a reduction in the rate of glucose synthesis (Reynolds et al., 2003). As shown in Table 2, age affects glucose levels in cattle as has been shown by Doornenbal et al. (1988) where glucose levels in calves were lower than those for mature animals. In growing animals, glucose requirement is determined by growth rate, which is set by metabolizable energy intake (Reynolds et al., 2003) whereas in mature animals only maintenance energy is required.

The physiological status of an animal also affects the glucose concentration (Otto et al., 2000). As shown in Table 3, glucose concentrations were higher in non-pregnant and non-lactating cows as compared to lacta-

Table 2. Serum components in young and mature cattle.

Serum components	<1 year	2-year-old	6-year-old
Urea nitrogen (mmol/l)	4.1	4.9	5.0
Glucose (mol/l)	3.8	3.7	3.7
Calcium (mmol/l)	2.2	2.3	2.3
Inorganic phosphorus (µmol/l)	2.5	1.8	1.6
Aspartate aminotransferase (U/L)	81.5	123.8	132.7
Creatinine (µmol/l)	98.1	107.2	106.5
Uric acid (µmol/l)	51.7	60.5	55.5
Protein (g/l)	72.6	71.2	75.6
Albumin (g/l)	39.3	37.2	38.3

Sources: Doornenbal et al. (1988) and Otto et al. (2000).

Table 3. Means and standard deviations of blood serum components for pregnant, non-pregnant and lactating cows.

Serum components	Physiological status					
	Pregnant		Non-pregnant		Lactating	
	Mean	SD	Mean	SD	Mean	SD
Urea nitrogen (mmol/l)	4.7	0.3	5.2	0.9	4.8	0.6
Glucose (mol/l)	2.0	0.8	3.0	0.8	1.6	0.5
Calcium (mmol/l)	2.1	0.2	2.3	0.3	2.0	0.2
Inorganic phosphorus (µmol/l)	1.7	0.3	2.1	0.3	1.9	0.5
Aspartate aminotransferase (U/L)	86.2	12.5	84.6	16.5	87.2	13.2
Creatinine (µmol/l)	95.1	39.1	101.6	12.8	99.7	16.5
Uric acid (µmol/l)	47.2	7.7	49.5	18.2	56.6	12.6
Total protein (g/l)	82.8	4.9	77.3	7.5	85.0	8.7
Albumin (g/l)	42.3	2.2	39.3	1.6	39.4	2.8

Source: Otto et al. (2000).

ting cows due to the high energy demand in lactating cows for milk production. Previous studies have shown that the percentage of total glucose supply oxidized is reduced in lactating compared to dry cows and tissue utilization of glucose decreases while there is an increase in use of lipid for energy (Reynolds et al., 2003). Grunwaldt et al. (2005) reported an effect of season on glucose levels shown by a significant increase in blood glucose levels in autumn (February) as compared to summer (May) (Table 4). Glucose levels decreases with an increase in body temperature and respiration rate of animals normally experienced in hot summer season. Feed quality also affects blood glucose levels. For example, Chimonyo et al. (2000) observed a significant reduction of the levels of plasma glucose in winter in cows.

Lipids important in the assessment of nutritional status of cattle include non-esterified fatty acids, cholesterol, β-hydroxybutyrate and lipoproteins. There is low variability in the blood levels of non-esterified fatty acids as compared to cholesterol which has moderate variability. Non-esterified fatty acids therefore have a high diagnostic value in the assessment of nutritional status as compared to cholesterol. The reason for moderate variability of cholesterol is not clear but can probably be attributed to its metabolic variation with the blood glucose levels. Effect of season on cholesterol levels is also not clear. Elevated levels of cholesterol, triglycerides, and phospholipids are indicative of copper deficiency. The essential nature of copper is due to its cofactor role at the active site of a number of enzymes (Engle and Spears, 2000).

Non-esterified fatty acids (NEFA) are released into the circulation as a direct result of lipid catabolism. Non-esterified fatty acids concentrations are commonly used in assessing energy status of dairy cows (Mayes, 2000; Adewuyi et al., 2005). Chimonyo et al. (2000) observed elevated NEFA levels in undernourished cows that were used for draught power. High NEFA values result in either elevated ketones or fat production by the liver (Oikawa and Katoh, 2002). Associated with fat in the very low density lipoproteins (VLDL) structure is a substantial amount of cholesterol. As a result, it has been suggested that NEFA to cholesterol ratio is more appropriate in assessing the energy status of animals. Serum NEFA

Table 4. Blood chemistry measurements from beef cattle in Mendoza plain, Brazil, in summer and autumn.

Parameters	Sampling season			
	Summer		Autumn	
	Mean	SD	Mean	SD
Urea nitrogen (mmol/l)	6.7	1.8	6.2	1.5
Glucose (mol/l)	3.1	1.2	4.2	0.8
Calcium (mmol/l)	2.0	0.2	2.1	0.2
Inorganic phosphate (µmol/l)	1.5	0.3	1.3	0.4
Aspartate aminotransferase (U/l)	49.0	17.7	26.0	12.5
Creatinine(µmol/l)	88.0	20.3	133.0	21.1
Albumin (g/l)	47.0	5.7	40.0	4.3

Source: Grunwaldt et al. (2005).

concentrations are more sensitive to changes in energy balance than body condition scoring in transition cow situations. B–hydroxybutyrate (BHB) and NEFA elevated concentrations indicate short-term negative energy balance and adipose tissue catabolism (Reist et al., 2002; Agenas et al., 2006). At present, measurement of beta-hydroxybutyrate concentration is most commonly used. However, beta-hydroxybutyrate concentrations may not be sensitive enough and can come from dietary sources (Agenas et al., 2006).

Blood chemical constituents related to protein metabolism

Proteins perform unique functions in the body. At present there is no single metabolite that can be measured, which directly reflects protein status. As a result, a combination of parameters needs to be utilized, including blood urea nitrogen (BUN), creatinine, and total protein, albumin, and creatinine levels. Albumin and total protein have low variability in blood. As a result they both have a high diagnostic value in the assessment of nutritional status as compared to creatinine which has low diagnostic value due to its high variability in blood. Serum albumin is a very sensitive and early nutritional indicator of protein status (Agenas et al., 2006) because its turnover is only 16 days. Deficiency of protein impairs both humoral and cell mediated immunity, thus predisposing an animal to diseases (Titgemeyer and Loest, 2001).

Total protein levels are lower in young animals and higher in mature animals whilst albumin levels are lower at birth and then increases (Doornenbal et al., 1988; Otto et al., 2000). Malnutrition decreases albumin levels. Total protein and albumin reflect availability of protein and their concentration decline in the face of protein deficiency. As shown in Table 3, total protein levels are low in non-pregnant non-lactating cows (Otto et al., 2000). Dietary protein nutrition or utilization and the associated effects on ovarian or uterine physiology have been monitored with urea nitrogen in plasma; concentrations above 19 mg/dl have been associated with altered uterine pH and reduced fertility in dairy cows (Butler et al., 1998). No marked age differences have been detected in albumin levels (Otto et al., 2000).

Monitoring of blood urea levels can be used for measuring protein status in cattle from different feeding regimes and seasons (Hammond, 2006). Values for urea within the optimum range (< 3.6 mmol/l) in cattle indicate that the effective rumen degradable protein (ERDP) is adequate. High blood urea levels could indicate a high protein intake or the excessive mobilization of muscle (Chimonyo et al., 2002). In ruminants a decrease in the blood urea concentration is related to low dietary intake of protein due to the recycling of urea from blood back to the rumen when dietary protein intake is low (Oulun, 2005). Grunwaldt et al. 2005 observed similar levels of urea nitrogen in summer and in autumn, as shown in Table 4.

The most common application of the use of blood urea nitrogen is as a retrospective diagnostic tool to analyze biological responses to protein or energy supplementation, change in pasture or forage on offer, or change in pasture management (Hammond, 2006). Serum urea concentration may also increase despite low-protein feeding if energy intake is restricted, which is thought to reflect increased breakdown of endogenous proteins for energy production, a decrease in renal reabsorption of urea and/or haemoconcentration (Oulun, 2005). High dietary protein (nitrogen) intake resulting in blood urea nitrogen of greater than 19 to 20 mg/dl has been associated with an altered uterine environment and decreased fertility (reduced conception rate, decreased pregnancy rate) in lactating dairy cows and heifers (Elrod and Butler, 1993; Butler et al., 1998).

Creatinine, a by-product of the breakdown of creatinine and phosphocreatinine in muscle, is most commonly used as an indirect indicator of renal function and its impact on blood urea nitrogen. Serum creatinine concentrations vary due to an animal's diet, breed, muscle mass

and sex (Otto et al., 2000; Miller et al., 2004; Hammond, 2006). Grunwaldt et al. (2005) also showed lower creatinine levels during the summer than in autumn, as shown in Table 4. Reduced concentrations of creatinine indicate prolonged active tissue protein catabolism (Agenas et al., 2006). An increasing muscle mass from animal walking long distances in search of pasture can increase serum creatinine levels (Otto et al., 2000).

Assessment of nutritional status using packed cell volume and haemoglobin levels

Packed cell volume (PCV) is the volume of erythrocytes expressed as a percentage of the volume of whole blood in a sample. It is the most accurate means of determining red blood cell volume and can be used to deduce total blood volume and haemoglobin levels. Several factors affect PCV levels. Higher haemoglobin and PCV values than the reference values could be attributed to the differences in ages of the animals (Grunwaldt et al., 2005). However Otto et al. (2000) reported no age effect on PCV values. No breed effects were observed between Aberdeen Angus and the Criollo Argentino on PCV values (Grunwaldt et al., 2005). Otto et al. (2000), however, observed a PCV value of 32% for Anguni cattle of Mozambique, which tended to be lower than Aberdeen Angus cattle thus showing breed differences. Reference levels for PCV and haemoglobin contents in indigenous cattle of Southern Africa raised under rural production conditions are largely unknown.

Packed cell volume could indicate anaemia, haemorrhage, bone marrow failure, destruction of erythrocytes, leukaemia, malnutrition or specific nutritional deficiency, multiple myeloma and rheumatoid arthritis (Jain, 1993; Kaneko, 1997). Packed cell volume values higher than the reference values could indicate dehydration due to diarrhoea, erythrosis and polycythermiavera. Conditions that can result in a low haematocrit include vitamin or mineral deficiency, cirrhosis of the liver and malignances (Kaneko, 1997). A decrease in haemoglobin indicates lack of amino acids, vitamins (especially Vitamins B12, E, folic acid and niacin) and/or minerals (Jain, 1993). Haemoglobin is the iron-containing oxygen-transport metalloprotein in the red blood cells of the blood in animals. Decrease of hemoglobin, with or without an absolute decrease of red blood cells, leads to symptoms of anaemia. Anaemia has many different causes, although iron deficiency is the most common cause. As absence of iron decreases heme synthesis, hypochromic red blood cells (lacking the red hemoglobin pigment) and microcytic red blood cells (smaller than normal) (Kneipp et al., 2006).

Mineral metabolism

To promote normal tissue growth, homeostasis, enzyme function, cell regulation, and immune function, it is imperative that minerals be maintained within narrow concentrations within the body (Underwood and Suttle, 1999). Minerals play a vital role in forage digestion, reproductive performance, and the development of bones, muscle, and teeth. Sub-clinical trace mineral deficiencies occur more frequently than recognized by most livestock producers (Underwood and Suttle, 1999). Calcium, phosphorus and magnesium have a high diagnostic value in determining the nutritional status of animals due to their low variability in blood. Mahusoon et al. (2004) observed marked breed differences in mineral metabolism in goats. Mineral levels have been shown to vary with seasons (Yokus and Cakir, 2006) whereas Grunwaldt et al. (2005) showed no significant differences in autumn and summer for inorganic phosphate and calcium levels (Table 4).

Calcium is the most abundant mineral in the body; approximately 98% functions as a structural component of bones and teeth. The remaining 2% is distributed in extracellular fluids and soft tissues, and is involved in such vital functions as blood clotting, membrane permeability, muscle contraction, transmission of nerve impulses, cardiac regulation, secretion of certain hormones, and activation and stabilization of certain enzymes whereas phosphorus is involved in every metabolic reaction and energy transfer within the body (Invartsen and Andersen, 2000). Phosphorus is required for normal milk production, growth, and efficient use of feed and by the rumen microorganisms in the digestion of cellulose and synthesis of microbial protein. Mineral absorption increases in the gastrointestinal tract while mobilization is increased in the bones (Invartsen and Andersen, 2000). Physiological status affects calcium levels in cattle, as shown in Table 2, where highest levels were obtained in non-pregnant and non-lactating dairy cows (Otto et al., 2000). It is not clear whether beef cattle show similar patterns. Season, however, was reported to have no effect on inorganic phosphate and calcium levels (Yokus and Cakir, 2006), as shown in Table 4.

Magnesium is an essential cation, involved in many enzymatic reactions, as a cofactor to adenosine triphosphatases. It is critical in energy-requiring metabolic processes, in protein synthesis, membrane integrity, nervous tissue conduction, neuromuscular excitability, muscle contraction, hormone secretion, and in intermediary metabolism (Laires et al., 2004). Serum magnesium concentration is maintained within a narrow range by the small intestine and kidney which both increase their fractional magnesium absorption under conditions of magnesium deprivation (Ghamdi et al., 1994). If magnesium depletion continues, the bone store helps to maintain serum magnesium concentration by exchanging part of its content with extracellular fluid (Laires et al., 2004). In dairy cows, magnesium levels are dependent on both physiological and seasonal variations (Yokus and Cakir, 2006). Serum magnesium levels reflect current daily intake rather than reserves, thus cattle are affected

by low magnesium dietary content (Whitaker et al., 1999). Grass tetany occurs when the level of magnesium in blood falls below a critical threshold (below 1.2 mg per 100 ml) (Herdt et al., 2000).

Liver enzymes

Aspartate aminotransferases (AST) enzymes are present in many tissues, particularly liver, striated and cardiac muscle, making it a good marker of soft tissue damage (Otto et al., 2000). Liver enzymes have low diagnostic value for nutritional status due to their high blood variability. Red blood cells contain AST which can leak into plasma before there is any visual evidence of haemolysis (Abutarbush and Radostits, 2003). Many conditions that produce a significant rise in creatinine kinase (CK) activity will also produce elevated to high levels of AST (Abutarbush and Radostits, 2003). Vitamin E and selenium deficiency in the diet causes nutritional muscular dystrophy and diagnosis is usually based on elevated levels of muscle enzymes (CK and AST) (Abutarbush and Radostits, 2003). Vitamins C, E and selenium are important in the protection of cellular membranes from free radicals, which cause peroxidation of the membrane lipids (Abutarbush and Radostits, 2003; Karakilc et al., 2005). In healthy cows, the serum enzyme activity is low or absent. Neither seasonal nor physiological variations have been reported on either Alanine transferase (ALT) or AST (Yokus and Cakir, 2006). In contrast, as is shown in Table 4, there are higher AST levels during the rainy season (49U/L) than in the dry season (26U/L). More significantly, Grunwaldt et al. (2005) observed breed differences in ALT levels, where the Criollo Argentino had almost twice the amount of ALT as compared to that of Aberdeen Angus cows.

Conclusions

Future prospects

To develop organized markets for promoting indigenous cattle products, there is need to develop parameters that objectively assess nutritional and health status of the animals while they are still growing. There is need to determine desirable breeds which maintains the least blood cholesterol levels. Breed differences and genetic variation within breeds in rate and efficiency of growth, disease resistance and tolerance, and meat quality can be assayed using blood metabolites so as to find genetically superior animals adapted to harsh environmental conditions.

Although body weight measurement and body condition scoring are easier to perform and are cheaper to determine, they have limitations that can be complemented by the use of blood metabolites and haematology. Metabolite profiling provides useful information such as the occurrence of negative energy balance, undernutrition and the presence of disease. These statuses are crucial to know in animals that are destined for sale or export, as they also determine the quality of the meat produced. Frequent monitoring blood parameters, for example once in every season, assists in diagnosing metabolic problems and determining animals that are metabolically superior on veld or to identify animals that require supplementary feeding.

In practice, metabolite herd testing has a number of constraints that need to be overcome. The major challenges include high skilled labour required for blood sampling, availability of sampling ingredients, expertise in processing and storing blood and, perhaps, the most important, the high cost of analysing the samples. There is, for example, need to use friendly and appropriate techniques for restraining and bleeding that minimise stress. Appropriate infrastructure, such as strong cattle handling facilities, should be erected. Many rural communities in Southern Africa, lack such facilities in good operational order. Communities and the farmers, thus, need to be educated on the need for determination and application of blood parameters as a tool to aid beef cattle management. This should destroy the generally held myth that animals are only handled when they are clinically sick or when they ready for slaughter.

The cost of analysing for blood samples is, in most cases, beyond the reach of many farmers, especially the resource-limited farmers in rural areas. Currently, determination of each of glucose, NEFA and urea costs about $7. In other words, conducting a full blood haematology and chemistry analysis costs in the region of $100 per animal (M. Chimonyo, personal communication). The cost of sample analysis can be reduced either by pooling samples or sampling from a few representative animals from the herd or population. Pooling can be done by appropriate physiologic states to allow interpretation of dynamic changes in "population means" over a period of time. Identifying animals should also be done from different physiological states, sex, ages or production systems. These factors are crucial in the correct interpretation of haematological or serum chemistry status of the animals.

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