EVALUATION OF ENERGY BALANCE OF FRIESIAN X BUNAJI DAIRY COWS USING MILK COMPOSITION BASED INDICATOR TRAITS

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ABSTRACT

The potentials of using milk composition as indicators of energy balance (EB) in dairy cows were evaluated. Milk composition traits (milk protein, fat and lactose percentages) from thirteen (13) primiparous and 47 multiparous (F_1) Friesian x Bunaji cows were studied. The milk composition was analyzed weekly from 4 to 300 days postpartum. The analyzed percentage milk fat, protein and lactose were used to calculate the other milk composition parameters. The mean estimates of EB based on milk measures for all the 3 stages of lactation were positive. However, the magnitude of the average estimates of the EB increased with stages of lactation; 21.99, 46.514 and 59.097MJ/d for stages 1, 2 and 3 respectively. The magnitude and direction of the correlations between EB and milk composition traits varied across stages of lactation; the correlation coefficient was relatively stronger in the 3rd stage than the 1st and 2nd stages of lactation. The potential indicators of EB identified from this study were the protein contained variables, such as milk protein content (MPC), fat-protein ratio (FPR), change in milk protein content (dmPc), change in fat-protein ratio (dFPR) and change in protein-lactose ratio (dPLR). These variables had strong relationship with EB both within and across lactation stages. However, dmPc seems to be the variable most common to all of these potential milk production variables. It had very strong and positive relationship with EB both within and across lactation stages. This suggested that high milk protein is associated with positive EB, while the decrease in milk protein content is associated with negative energy balance (NEB). Therefore, the dynamics of changes in milk composition measures during lactation could be used to monitor the EB status of dairy cows.

Keywords: Crossbred cows, Friesian x Bunaji cows, Dairy, Lactation stages, Milk protein content, Energy balance, Indicators, Fat-protein ratio, Protein-lactose ratio

INTRODUCTION

The term energy balance (EB) is used to describe the relationship between dietary energy intake and energy utilization. It is the different between the net energy intake and the net energy required for maintenance, milk production, growth and other activity (Lucy *et al.,* 1991; Tamminga, 2006). In breeding and genetic improvement program, it is desirable to understand the energy profile changes of animals under selection for optimum yield, so as to identify animals that are genetically predisposed to retain energy and avoid lengthy intervals due to negative energy balance (NEB) state (Banos *et al.,* 2005).

However the traditional way of measuring EB using input-output measures requires the measurement of all energetic profiles (feed intake) and output (milk, fetus, growth) and is not feasible in large populations under current commercial condition (Coffey *et al.,* 2001; Friggens *et al.,* 2007). Therefore, there is interest in identifying other traits, which could serve as indicators of EB. Body condition score (BCS) is one of these traits (de Vries and Veerkamp, 2000; Veerkamp *et al.,* 2001). It is widely used in many species to assess body composition and energy status of animals. However, BCS is a subjective measure and routine recording of BCS is not a common practice on most dairy farms (de Vries and Veerkamp, 2000). Another alternative indicator of energy status is the use of various blood metabolites such as β-hydroxybutyrate (BHB), non-esterified fatty acids (NEFA) and insulin which had been reported to be strongly correlated with EB (Reist *et al*., 2002; Clark *et al.,* 2005). However, analyses of these blood metabolites are expensive and are currently not commercially available, but only feasible on experimental farms. This hampers the use of these methods on-farm. Thus, another option that has been put forward for measuring EB of dairy cows is the use of changes in milk composition measures, such as milk fat, protein and lactose (Heuer *et al.,* 2001; Reist *et al*., 2002; Friggens *et al.,* 2007). This is based on the premise that EB status of a cow directly affect the quality and quantity of the milk produced. If this option has adequate level of accuracy it will be an easy and attractive one, because it could provide a cheap and reliable indicator that can be used as management tool to monitor EB status of dairy cows during lactation. It is therefore, hypothesized that changes in milk composition variables and ratios of milk components can be used to monitor EB status of dairy cows during lactation. One way of validating this hypothesis is to assess the relationship between the milk composition variables and the EB at different stages of lactation. A clear understanding of this relationship in dairy cows would enable the development of reliable indicator of energy balance in dairy cows (Friggens *et al.,* 2007).

Therefore, this study had the objective to identified milk combination measures that can best be used as reliable indicators of energy balance in dairy cows.

MATERIALS AND METHODS

Experimental Site: The study was conducted on dairy herd of National Animal Production Research Institute (NAPRI), Shika, Nigeria, located between latitude 11^0 and 12^0N at an altitude of 640 m above sea level, and lies within the Northern Guinea Savannah Zone (Oni *et al.,* 2001). The mean annual rainfall in this zone is 1,100 mm, which commenced from May and last till October, with 90% falling between June and September (Oni *et al.,* 2001).

Animal Management: The cows used for this study were raised under semi intensive management system, whereby the animals were grazed under the supervision of herdsmen on both natural and paddock–sown pasture for 7 – 9 hours per day, while hay or silage supplemented with concentrate mixture of cotton seed cake and grinded maize were offered during milking. They had access to water and salt lick *ad-libitum*.

Data Collection: Data for this study were collected from 13 primiparous and 47 multiparous (F_1) Friesian x Bunaji cows from January 2011 to December 2013. Cows were milked manually (morning and evening) using hand daily. This resulted in a cumulative test day milk yield record of 36,120 from the 60 cows. The milk samples for the determination of fat, protein and lactose percentages were taken once per week starting from 4 days postpartum to the end of lactation of each cow. The milk samples collected were frozen (-20^{o}C) immediately after collection until analysed. The milk composition analysis was carried out at the Food Science and Technology Laboratory of Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. The fat content was determined by Gerber method (FAO, 1977), while the crude protein content was determined by Kjeldahl method (AOAC, 2000). Lactose content was determined by titration method (Laboratory Manual I, 2005). The yield values and the ratios were derived from the values of fat, protein and lactose content (Friggens *et al.,* 2007; Lφvendahl *et al.,* 2010). The following seventeen (17) milk composition profiles were used: milk fat content (MFC), milk protein content (MPC), milk lactose content (MLC), milk yield (MY), milk Fat yield (MFY), milk protein yield (MPY), milk-lactose yield (MPY), fat-protein ratio (FPR), fat-lactose ratio (FLR), protein-lactose ratio (PLR), changes in milk yield (dmy), changes in milk protein content (dmPc), changes in milk fat content (dmFc), changes in milk lactose content (dmLc), changes in fat protein ratio (dFPR), changes in fat lactose ratio (dFLR) and changes in protein-lactose ratio (dPLR). Note: Abbreviations starting with "d" are the current minus the previous value of the milk measures in question. Yield values are in kilograms/day (kg/day), content values are in percentages (%) and ratios are unitless. The study was conducted in accordance with Institutional guidelines on the care and use of animals for scientific research, and in compliance with generally accepted rules of best practice worldwide.

Calculation of Energy Balance: The energy balance (EB) was calculated weekly from the measurements of milk composition variables using the equation described by Lφvendehl *et al*. (2010) as follows: EB = 132.769 + 13.0675 x MFC – 140.304 x FPR – 95.1219 x diff (MY) - 172.65 x diff (FPR) + 802.306 x diff(mPy), where: MFC = milk fat content, FPR = fat-protein ratio and MY = milk yield. The three "diff()" variables are the current minus the previous value of the milk measure in question; diff(MY), diff(FPR), and the difference in milk protein yield, diff(mPy).

Stages of Lactations: Three stages of lactations were defined according to days in milk (DIM) as: Early-lactation (0 to 100 days); Mid-lactation (100 to 200 days) and Late-lactation (200 to 305 days). The first stage represents the period when both protein and lipids mobilization likely occur. The second stage represents lipid mobilization and possible protein deposition. The third stage represents both lipid deposition and possible protein deposition (Lφvendehl *et al.,* 2010).

Data Analysis: The relationship between energy balance and milk composition measure was analyzed using Pearson's correlation (SAS, 2000).

RESULTS AND DISCUSSION

The mean estimates of EB based on milk measures for the 3 stages of lactation were all positive and increased with stages of lactation; 21.99, 46.514 and 59.097MJ/d, for early-, mid- and late-lactation, respectively (Table 1).

Table 1: Energy balance of Friesian x Bunaji dairy cows estimated in each of the lactation stages

Stages of lactation	Means
Early- lactation	21.99 ± 76.69
Mid-lactation	46.51 ± 94.62
Late-lactation	59.10 ± 41.15
Across stages	59.20 ± 58.69

This suggested that most of the cows used for this study did not experience strong energy deficit at least, to a critical level that the body reserves were mobilized to an alarming level during the lactation period. However, there was a phenotypic trend that showed that the EB status of the cows was low during the early lactation and high at the late lactation. This suggested that the animals could stand the risk of energy deficit in the early lactation if appropriate management measures are not taking to ensure that the cows has enough body reserves (good body condition) prior to calving. It has been reported that dairy cows, especially the high yielding ones suffers negative EB during early lactation, because the amount of energy required for maintenance of body tissue functions as well as the high milk production exceeds the amount of energy cows can consume (Reist *et al.,*2002; Konigsson *et al.,* 2008). However, the extent of energy deficit depends not only on the amount of milk produced by the cow, but the quantity and quality of feed intake (Buttchereit *et al.,* 2010). That is why even the low to moderate yielding cows of the tropics suffers negative EB. The increase in the EB across the 3 stages of lactation from early to the late lactation was an indication of the recovery rate of the cows from the low EB status during the early lactation to higher EB at the late lactation. The degree of the energy deficit in the early post-partum period and the recovery rate from low or negative EB are critical for the health status and productivity of the dairy cow (Reist *et al.,* 2002). The correlations of EB estimates between stages of lactation was weak except the correlation between EB in early and mid-lactation which was high but negative (-0.768) (Table 2).

Table 2: Estimated correlations between energy balance of Friesian x Bunaji dairy cows at different stages of lactation

	Energy balance		
	Stages of lactation		
Stages of lactation	**EB_1**	**EB_2**	**EB_3**
EB_1	-		
EB_2	-0.768	-	
EB_3	0.102	0.271	-

The observed weak correlation between EB estimates at different stages of lactation suggested the existence of some level of independent between the stages of lactation. Therefore, EB as such could be a very different biological trait in different stages of the same lactation, first because it can change in magnitude and direction from positive to negative, and second because it involves different metabolic efficiency in the different stages (Emmans, 1994). For example, it has been reported that the first stage of lactation represents the period when both protein and lipids mobilization likely occur, and that the second stage represents lipid mobilization and possible protein deposition, while the third stage represents both lipid deposition and possible protein deposition (Friggens *et al.,* 2007; Lφvendahl *et al.,* 2010). Furthermore, Lφvendahl *et al.* (2010) reported that the potential application of EB information differs with stages of lactation from being ketosis risk related (very early stage), to fertility related (early to middle stage), and finally of importance for preparing for the next lactation (in the late stage and dry periods).

The correlated relationship between EB and milk composition variables within and across lactation was relatively stronger in the late lactation than the early- and mid-lactation (Table 3). The magnitude of the correlation coefficients increases across the lactation stages. In early lactation (r_1), only milk protein content (MPC -0.649), fat protein ratio (FPR 0.559) and protein-lactose ratio (PLR - 0.327) as well as changes in milk protein content (dmPc 0.988), changes in fat-protein ratio (dFPR 0.587) and changes in protein-lactose ratio (dPLR 0.545) were significantly ($p<0.01$) correlated with EB, but at the late lactation period (r_3), all the milk composition variables were strongly correlated ($p<0.01$) with EB, except protein-lactose ratio. Also, the direction of the correlation coefficients generally changes across lactation stages. For example, the correlation between EB with milk protein content and milk lactose content were negative at the early-lactation but positive at the mid- and late-lactation. In the same vein, the correlation between EB with milk fat content, milk fat yield, milk protein yield, fat-lactose ratio and changes in fat protein ratio were negative in the early- and mid-lactation but positive in the late-lactation. The observed changes in the magnitude and direction of the correlation coefficient between EB and milk composition variables across the lactation stages is probably an indication of the metabolic changes that the animal underwent during the lactation period.

The strong positive relationship of milk protein content and it rate of change (dmPc) with EB suggested that high milk protein is associated with positive energy balance, while the decrease in protein content is associated with negative energy balance. The physiological bases for this relationship are related to the nutritional and metabolic activity that influences the amount of glucose available for efficient synthesis of microbial protein in the rumen. Inadequate intake of fermentable carbohydrates can cause insufficient protein synthesis by ruminal bacteria, thereby compromising the flow of amino acids to the udder; consequently, milk protein content will decrease (Gürtler and Schweigert, 2005). On the other hand, adequate intake of fermentable carbohydrate such as silage and energy concentrates would provide sufficient amount of energy in form of glucose for microbial protein synthesis there by

Table 3: Pearson's correlation of energy balance of Friesian x Bunaji dairy cows with milk traits in the three lactation periods

Milk Traits	Energy Balance			
	Early (r_1)	Mid (r_2)	Late (r_3)	r_{All}
Milk fat content (%)	-0.287	-0.339*	-0.541*	-0.349*
Milk protein content (%)	-0.649**	0.645**	0.754**	-0.616**
Milk lactose content (%)	-0.203	0.050	0.896***	-0.375*
Milk fat yield (kg)	-0.067	-0.161	0.799***	-0.186
Milk protein yield (kg)	-0.203	-0.439*	0.902***	-0.332*
Milk lactose yield (kg)	0.096	0.122	0.920***	-0.177
Fat-protein ratio (FPR)	-0.559**	-0.660**	-0.756**	-0.296
Fat-lactose ratio (FLR)	-0.161	-0.291	0.592**	0.060
Protein-lactose ratio (PLR)	-0.327	-0.576**	-0.045	-0.203
Change in milk fat content (dmFc)	0.260	0.733**	0.879***	0.656**
Change in milk protein content (dmPc)	-0.988***	0.999***	0.999***	0.996***
Change in milk lactose content (dmLc)	0.244	0.121	0.969***	0.533*
Change in fat-protein ratio (dFPR)	-0.587**	-0.625**	0.872***	0.644**
Change in fat-lactose ratio (dFLR)	0.010	0.334*	0.491*	-0.002
Change in protein-lactose ratio (dPLR)	0.545**	0.643**	0.599**	0.519*

**= P< 0.05, ** < P =0.01, *** = P< 0.001, r_1, r_2, r_3, r_{all} = correlation coefficients between EB and milk traits in the first, second, third and across all stages of lactation, respectively, Variables abbreviations starting with "d" are the current minus the previous values of milk measures in question*

increasing the flow of amino acids to the udder for synthesis of milk protein by the alveoli cells (Alphonsus *et al*., 2014). In addition, fermentable carbohydrates increase the energy density of a diet, which improves the energy supply and determines the amount of bacterial protein produced in the rumen. The extent to which ammonia is used to synthesize microbial protein is largely dependent upon the availability of energy generated by the fermentation of carbohydrates. Therefore, glucose may be the key linkage between the milk protein content and the energy balance (Alphonsus *et al*., 2014).

The shortage of glucose for milk protein synthesis in the udder is not only due to inadequate consumption of fermentable carbohydrates, but also due to excessive selection for high milk production. It has been reported that cows selected for high milk production have relatively low glucose level during lactation (Snijders *et al.,* 2001). This shortage in glucose can reduce the synthesis of milk protein from the udder. Thus, low milk protein content would be found in cows with high potential for milk production (Buckley *et al.,* 2000). The genetic relationship between milk protein content and energy balance is an area of continuing research.

Therefore, it is possible that there are two types of low protein content in cows. One may be inherently low protein cows which cannot be altered by nutrition or management to any great extent (Koenen and Veerkamp, 1998). The second type may be nutritional or environmentally induced, particularly in a low concentrate pasture based production. This second type can easily be corrected by nutritional management (Yang, 2009).

The indicators for EB suggested in this study were based on variation among cows from within-herd analysis. It could however, be hypothesized that these indicators are robust across herds because they have proper biological explanation, and some of the between herd differences in absolute protein content might be accounted for, and changes in protein content during lactation (adjusted for year and season) might be relatively unaffected by herd differences other than EB. If this hypothesis is proven to be correct, then changes in milk composition variables could be used to identify EB-related herd problems, and could also help in identification of potential problems associated with nutritional deficiency and NEB (Alphonsus *et al.,* 2013), especially because the measurement of EB itself is very cost intensive and cumbersome.

Therefore, milk component could serve as a measure of energy balance status and might be used as a selection criterion to improve metabolic stability.
Thus, the hypothesis that milk yield and composition variables can be used to monitor the EB status of dairy cows during lactation seems promising.

Conclusion: The potential indicators of EB in this study were the protein contained variables, such as milk protein content, fat-protein ratio, changes in milk protein content, changes in fat-protein ratio and change in protein-lactose ratio. These variables had strong relationship with EB both within and across lactation stages. However, change in milk protein content seems to be the variable common to all of these potential milk production variables. It had very strong relationship ($p<0.01$) with EB both within and across lactation stages. Therefore, the dynamics of changes in milk composition variables during lactation could be used to monitor the energy balance status of dairy cows and to identify variation among animals in energy balance.

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