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Changes in calculated residual energy in variable nutritional environments: An indirect approach to apprehend suckling beef cows' robustness

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ABSTRACT

The major perturbation that beef cows have to face in extensive livestock systems is changes in feed resource availability. The ability of beef cows to face variable nutritional environments (robustness) involves adaptive processes that drive adjustments in the energy allocation toward life functions. This study proposes an indirect approach to quantify the modulation of energy allocation over a changing nutritional environment. The concept of residual energy (E_{resid}), defined as the net energy intake minus the energy secreted in milk and deposited in tissues, was used to investigate the variation in energy allocation priority for maintaining productive traits. In this study robustness was assessed by the difference in E_{resid} between cows experiencing either variable or non limiting nutritional trajectories and differing in body reserves at calving. Forty multiparous Charolais suckling cows, differing in their body condition at calving (moderate (M, $n=19$): $BCS_c=2.0\pm0.04$ (scale 0–5)) vs fat (F, $n=18$): $BCS_c=2.8\pm0.08$) were used. They were submitted to two energy levels during the first 120 days *post-partum* (P1): Control (MC ($n=9$) and FC ($n=9$)) vs Low (ML ($n=10$) and FL ($n=9$)). The average energy intake, expressed in net energy for lactation (NE_L), was 90.7 and 54.7 MJ/d/cow for C and L cows, respectively. Subsequently (P2, 120–196 days *post-partum*) all the cows were turned out to a permanent pasture. BW, body condition and milk production were regularly measured in P1 and P2. Body lipid reserves were assessed at calving, end of P1 and end of P2 by measuring adipose cell diameter. The overall milk production was similar between groups of cows over the 2 phases of the changing nutritional trajectories highlighting the robustness of beef cows to achieve this function. During P1, L cows lost BW and body lipid reserves. During P2, BW and BCS gains were similar in FL and ML cows. At the end of P2, FL and ML cows weighed 20 and 10 kg less than FC and MC cows, respectively. Considering both experimental periods (P1+P2), E_{resid} was 23% lower in L than in C cows ($P<0.05$). This difference was observed regardless of BCS_c, showing that thin beef cows withstood the change in nutritional trajectory after calving similarly to the fatter ones. E_{resid} changes reflect the ability of beef cows to preserve energy allocation toward life functions in changing nutritional environments and may be viewed as indirect criteria of robustness.

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1. Introduction

Concept of robustness is a major concern in extensive livestock production systems where animals have to cope with environmental perturbations. In its broadest definition, the robustness is a property that accounts for the ability of system to maintain its functions despite external/or internal perturbations (Kitano, 2004). At the animal level, robustness is viewed as its ability to maintain itself (i.e. survive and produce) in a broad variety of environments or to be able to face short and long-term perturbations (Knap, 2005; Strandberg, 2009). One of the major perturbations beef cows have to cope with in extensive livestock systems is changes in feed resources' availability and quality over the productive cycle. Various studies have shown that nutrition level may affect productivity traits in beef cows such as growth, milk production, reproductive performance and longevity (Blanc et al., 2006; Jenkins and Ferrell, 1994; Osoro and Wright, 1992). However, studies mainly conducted with dairy cows revealed that life functions (growth, reproduction (including pregnancy and lactation), health…) are not affected to the same extent when the female experiences undernutrition periods. In a constrained environment, trade-offs between life-functions may occur (Blanc et al., 2006; Friggens and Newbold, 2007) as adaptation to changes in nutrients availability involves modifications in nutrient partitioning. Such modifications in resource allocation will allow for varying priorities to the robustness of some of these life functions (Douhart, 2013; Friggens and Newbold, 2007; Friggens et al., 2013). Numerous studies have considered the question of energy allocation in high-producing dairy animals. Maintenance of milk yield is a good indicator of the priority given to the milk production function. Under constraining environments milk production may decrease but nutrient allocation for lactation remains a priority and may have consequences on fertility (Blanc et al., 2006; Friggens and Newbold, 2007; Martin and Sauvant, 2010). Less attention has been paid to the robustness of suckling beef cows that would take into account trade-offs between life functions and thus between production traits (Freetly et al., 2000; Johnson et al., 2003). Indeed, contrary to dairy cows, milk yield of beef cows is moderate (8–10 kg/cow/day in Charolais cows) and does not change much with underfeeding reflecting the priority given to maternal investment in calf viability (Houghton et al., 1990; Petit and Agabriel, 1993).

From a systemic point of view, the cow is considered as a dynamic system that takes up energy from the environment to maintain its functions over the productive cycle. It is well documented that energy partition changes with stage of lactation (Kirkland and Gordon, 2001) and that the various metabolic pathways, e.g. lipogenesis and lipolysis, are up or down-regulated at different stages of the productive cycle (Chilliard et al., 1998; Friggens and Newbold, 2007). The net result of such changes is that all life functions are not impacted in equal proportion when nutrient supply changes. Considering such a systemic approach, net energy fluxes can be summarized using the following equation (1) $EI = E_l + E_y + E_r + E_{resid}$, where EI represents the net energy intake, E_l the net energy allocated to milk yield, E_y the net energy retained by the foetus and the gravid uterus, and E_r the net energy mobilized ($E_r < 0$) or retained ($E_r > 0$) by tissues. When net energy intake is calculated from Feed Table values, the last term of this equation, E_{resid} refers to the difference between net energy intake and the theoretical energy allocated to milk production, tissue growth and reserves, so that E_{resid} accounts for energy not directly allocated to productive functions. More precisely E_{resid} and its variations, expressed in net energy for lactation, correspond to the energy for maintenance which covers fasting heat production, heat of voluntary activity and of thermal regulation and part of heat of fermentations, digestion, absorption and metabolism (Williams and Jenkinks, 2003), errors in measurements and estimations of intake (NE_L of milk) as well as adjustments of requirements and of partial efficiencies of utilization of diet metabolizable energy (kl, kf, kp). Individual components of E_{resid} are not easily measurable in practice. Consequently, we considered that E_{resid} reflects the adjustments in energy allocation which occur when the cow undergoes a changing nutritional trajectory and is proposed as a criteria to indirectly estimate robustness.

The objectives of this study were to investigate in beef cows (i) the difference in E_{resid} between cows experiencing a variable nutritional trajectory (energy restriction followed by refeeding) and cows experiencing a non limiting nutritional trajectory as a criteria of adjustment in energy allocation to functions other than milk production and tissue gain, and (ii) the influence of body condition at calving on E_{resid} changes.

2. Materials and methods

The experiment was carried out at the INRA experimental farm in Laqueuille (Auvergne, France) from January to July 2010. Animals were raised in conditions compatible with national legislation on animal care (Certificate of Authorization to Experiment on Living Animal no. 7740, Ministry of Agriculture and Fish Products, Paris, France) and was approved by the regional ethics committee (Approval no. A63.189.04).

2.1. Experimental design

Forty multiparous Charolais cows (5 ± 1.6 years and 802 ± 66 kg at calving) were involved. The experimental design was a 2×2 factorial combining two body condition scores at calving (BCS_c, Fat (F) and Moderate (M) and two nutritional net energy levels (Control (C) and Low (L)). After calving and during the first 120 days post-partum (constraining period, P1), half of the cows experienced a nutritional restriction during the winter indoor period while the others were fed above requirements. Calving was grouped in early February. At turnout, all cows were reared at pasture in non-limiting conditions for a 76-day period (recovery period, P2, from May to end of July). Cow–calf pairs grazed the same permanent pasture, where continuous suckling was allowed. For reproduction a bull was introduced in the herd at turnout and removed after 2 months.

2.2. Constitution of initial body condition score

The two groups of cows of F or M body condition were created during a 4-month pre-experimental period (P0, from October to calving). Groups were balanced for initial BW (F: 836 ± 63 and M: 845 ± 44 kg) and expected calving date.