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Biological implications of longevity in dairy cows: 1. Changes in feed intake, feeding behavior, and digestion with age

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ABSTRACT

Milk production strategies focusing on longevity and limited use of concentrate are receiving increasing attention. To evaluate such strategies, knowledge of the development with age of animal characteristics, particularly digestion, is indispensable. We therefore investigated the development of feed intake, chewing activity, and digestion in 30 lactating Brown Swiss cows (876–3,648 d old) and 12 heifers (199–778 d old). We also studied whether age effects were exhibited differently in animals selected from herds subjected for 11 yr either to a forage-only or to a forage-concentrate feeding regimen. Forages consisted of grass hay (the only feed for heifers), corn silage, and grass pellets. Measurements lasted for 8 d, where amounts and composition of feeds, feces, and milk were recorded and analyzed. Ruminal pH data and eating and rumination activity were assessed by pH sensors put into the rumen and halter-mounted noseband sensors. The mean retention time of feed particles was assessed using Cr-mordanted fiber and data were used to calculate dry matter gut fill. Data were subjected to regression analyses with age and feeding regimen as explanatory variables, and body weight, milk yield, and proportion of hay in forage as covariates. This allowed separating age-related changes of body weight and milk yield from independent age effects and correcting for differences in preference for individual forages. In cows, organic matter intake increased with age (from slightly below to above 20 kg/d), as did mean retention time and gut fill. Digestibility of organic matter did not show a clear age dependency, but fiber digestibility had a maximum in cows of around 4 to 6 yr of age. Ruminal pH and absolute eating and rumination times did not vary with cow age. Young and old cows chewed regurgitated boluses more intensively (60–70 times) than middle-aged cows (about 50 times). Effects of feeding regimen were small, except for fiber intake and rumination time per unit of intake, owing to the different fiber content of the diets. No significant interactions between age and feeding regimen were found. Heifers spent more time eating and ruminating per unit of feed than cows, which resulted in a high fiber digestibility. Irrespective of the feeding regimen tested, older cows maintained intake and digestion efficiency with longer retention times and chewing rumination boluses more intensively. The results support efforts to extend the length of productive life in dairy cows.

Key words: lactation number, digestibility, digesta passage time, ruminal pH, rumination

INTRODUCTION

Milk production by dairy cows has been globally intensified by favoring genotypes with high daily milk yields (Miglior et al., 2005). These cows need proportionately fewer nutrients for maintenance and are particularly efficient in transforming nutrients into milk (Flachowsky and Brade, 2007; Prendiville et al., 2009), a phenomenon called "dilution of maintenance" (Capper and Bauman, 2013). The disadvantage of this high-yield strategy is that increasing amounts of concentrate are required, resulting in resource-intensive production that is in direct competition with human food supply (Oltjen and Beckett, 1996; Kiefer et al., 2014). Furthermore, the average number of parities per cow in high-yield strategies is decreasing or, at best, stable at a low level (e.g., 2.6 to 3.3 in the United States and Germany; Hare et al., 2006a; Knaus, 2009; Rohde et al., 2009). Even though involuntary culling due to different diseases or poor reproductive performance is

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more frequent than voluntary selection, a substantial proportion of the herd is culled exclusively to accelerate breeding progress for performance (Hadley et al., 2006; Pinedo et al., 2010). A short productive lifetime of cows requires additional rearing of replacements for culled cows, which is a rather unproductive period, as only meat from the culled cows is contributing to food production. Rearing takes at least 2 yr (Hare et al., 2006b), which is equivalent to almost half of the entire lifetime of dairy cows under current conditions. Therefore, increasing the longevity of cows enhances the dilution of the nonproductive stage by a longer productive lifespan.

To develop strategies for sustainable dairy production based on an increased length of productive life, knowledge about nutrient intake and digestion characteristics of animals at higher ages is indispensable. Results from Hayirli et al. (2002) and Jensen et al. (2015) suggest that feed intake capacity in dairy cattle increases with age. For other herbivorous species, such as deer, the capacity of the rumen-reticulum was reported to proportionately increase with age along with ruminal retention time (Veiberg et al., 2009; Duarte et al., 2011). Graham (1980) showed an increase in nutrient digestibility from weaner lambs to 6-yr-old sheep. Pérez-Barbería and Gordon (1998) stated in their review that improved chewing ability and modified chewing behavior can compensate for decreasing tooth effectiveness during lifetime; both influence the degree of feed comminution and, thus, feed degradability. Tooth effectiveness and feeding behavior have also been used to explain higher feed intake rates in mature compared with young cows (Pérez-Barbería and Gordon, 1998; Boudon et al., 2009). Furthermore, differences in diet composition (particularly fiber and its digestibility; Riaz et al., 2014) could result in different age trends in intake and digestion. Most of the recent literature on age effects in cattle is limited to the distinction between primiparous and multiparous cows (e.g., Maekawa et al., 2002b; Wathes et al., 2007; Devries et al., 2011) or groupings of cows across several lactations (e.g., >3, Fall et al., 2008; >4, Keene et al., 2004). In addition, cows in experiments are usually only chosen from a restricted age range, and thus older cows are often deliberately omitted.

Therefore, the objective of the present study was to determine if any changes in digestion occurred with age in dairy cattle continuously distributed over a large age range. Age effects were tested in 2 different feeding regimens (zero concentrate diet vs. control diet including concentrate). As a first step, nutrient intakes as well as feeding and digestion characteristics in heifers and cows of different ages (0.5–10 yr) were investigated. Three hypotheses were tested. (1) Dairy cattle increase their intake capacity with age, which allows them to increase intake without compromising ruminal fermentation conditions, digesta retention, and digestibility. (2) As chewing efficiency changes with age, cattle show a curvilinear development of chewing and rumination activity. (3) The age effect depends on the feeding regimen. The age-related changes were expected to go beyond the more obvious ones occurring from the transition from the heifer state (nonlactating) to primiparous cows and the subsequent transition from primiparous to multiparous cows. As a second step, methane emissions and efficiency were investigated as decisive criteria for environmental sustainability of longevity strategies in dairy production (described in Grandl et al., 2016).

MATERIALS AND METHODS

Animals and Feeding

The experiment, carried out from October 2013 to February 2014, was approved by the veterinary office of the Swiss canton of Zurich (149/2013).

Thirty lactating cows and 12 heifers of the Brown Swiss breed were selected from the 2 herds of the Agricultural Education and Advisory Centre Plantahof (Landquart, Switzerland). These herds were managed with different feeding regimens since 2003, and replacement was exclusively done within feeding regimen. Concentrate was completely omitted in one feeding regimen (**0-CONC**). In the other feeding regimen, the diet for the lactating cows included concentrate (5 kg/d per cow, 2 types either rich in energy or in protein were given in a ratio of 3:2). This was referred to as a control feeding regimen (**CTRL**), as this is a representative feeding practice for higher-yielding dairy cows. Year-round, animals in both feeding regimens received similar forages (hay, fresh grass or grass silage, corn silage, and pellets made from artificially dried grass, supplemented with NaCl and minerals). Cows were kept in a tiestall barn and treated identically. Sires used for AI were the same in both feeding regimens. All heifers of both feeding regimens were raised together on the same forage-only diet. After parturition they were allocated to the respective feeding regimen into which they had been born.

The animals (including the nonlactating heifers) were selected to achieve a maximum age spectrum and were balanced for feeding regimens and DIM. The age range covered a span from 199 to 3,648 d for CTRL and 310 to 3,640 d for 0-CONC (weaned calves to cows in the seventh lactation; details given in Table 1). The experiment was conducted in 7 subsequent runs during which 6 animals were subjected to the experimental procedures in parallel. The procedures lasted for a total of