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Effects of nutrition on the fertility of lactating dairy cattle

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ABSTRACT

This meta-analysis of 39 experiments containing 118 treatments explored the effects of diet interventions in early lactation on the proportion of dairy cows pregnant to artificial insemination (AI; pregnancy to AI) and on calving to pregnancy interval. It also identified factors that may explain variation in these responses. The objectives were to identify effects of diet on reproduction, rather than differences between specific dietary interventions. The examination of calving to pregnancy interval used the more traditional method of analyzing differences between a treatment and the reference treatment used for comparison within a given experiment. The systematic review identified fewer experiments (n = 39) than had been expected. Four different multivariable models including the random effect of experiment were used to examine the effects of CPM-Dairy (version 3.08) estimated diet and production variables on proportion pregnant to AI. These models examined (1) output of products, (2) balance or duodenal availability of nutrients, (3) intake of nutrients, or (4) percentage of nutrients in the diet. The multivariable models identified positive associations between estimated increased fatty acid intake [incidence rate ratio (IRR) = 1.0003 ± 0.0001g/d; ±standard error], starch intake (IRR = 1.061 ± 0.029 kg/d), metabolizable energy balance (IRR = 1.004 ± 0.002 MJ/d), and duodenal C14:0 (IRR = 1.008 ± 0.004 g/d) availability with the proportion of cows pregnant to AI, whereas rapidly fermentable sugar intake (IRR = 0.813 ± 0.054 kg/d), percentage of sugar in the diet (IRR = 0.960 ± 0.015%), and milk protein yield (IRR 0.922 ± 0.022 g/100 g per day) were associated with a reduced proportion of cows pregnant to AI. There was no multivariable model developed to assess variables associated with calving to pregnancy interval but, univariably, increased metabolizable energy balance was associated with a shorter calving to pregnancy interval whereas increased milk production was associated with longer time to pregnancy. Increased intake of some AA, particularly threonine and lysine, were associated with a longer calving to pregnancy interval. It is clear nutritional management around calving can influence reproductive success. The importance of dietary fats and increased energy and protein balances in early lactation for improved fertility outcomes is supported and suggests that starch and sugars may have different effects on the proportion of cows that are pregnant to AI. This work also highlighted a need for further focused field studies exploring the roles of specific fatty acids, AA, phosphorus, and carbohydrates on reproduction.
Key words: carbohydrate, fats, fertility, protein

INTRODUCTION

Poor reproductive performance of lactating dairy cattle is a complex disorder that reflects associations with intensification of production and increased milk production (Butler, 2000; Lucy, 2001; Lean et al., 2008; Berry et al., 2014). However, it is difficult to determine a causal basis for the decrease in fertility, as genetics and environment have changed markedly over the last decades. Although some of the decline in fertility observed in the past is associated with genetic selection for greater milk production, the heritability of reproductive disorders is weak (Pryce et al., 1997; Berry et al., 2014). This suggests that much of the decline previously observed was associated with changes in nutrition, housing, and herd management and interactions of these environmental changes with genetics.

Nutritional influences on fertility have been examined and frequently reviewed (Butler, 2000; Bisinotto et al., 2012; Friggens et al., 2013), but difficulties and inconsistencies in study design occur. Studies must have large numbers of experimental units to identify biologically and economically important differences

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in proportion of cows pregnant (Lean et al., 2016). Nutritional influences during the transition period (±4 wk of calving) may be of particular importance (Overton and Waldron, 2004), but it is clear that the effect of diet on fertility during this period is complex and multifactorial. Further, confounding is present in nutritional experiments, as the addition of one nutrient inherently alters concentrations of other nutrients in the diet (Lean et al., 2012). Nutrients may also interact to alter availability, uptake, or production of other nutrients and influence energy partitioning and future milk production beyond the period of immediate intervention (Block, 1984; van Saun et al., 1993; Degaris et al., 2008; Lean et al., 2014). Therefore, although experiments examining single nutritional interventions are essential to develop understandings of dietary components on reproductive outcomes, responses can be difficult to evaluate due to the potential for confounding. Meta-analysis using published literature provides the opportunity to combine studies and overcome the confounding caused by changes in single diets. It also allows the use of existing data to address hypotheses that could not be addressed previously, increases study power, and provides measures of the variation, or heterogeneity, of results among a group of experiments (Lean et al., 2009).

The effects of some nutritional interventions on pregnancy and time to pregnancy have been examined using meta-analysis (de Veth et al., 2009; Rabiee et al., 2010; Lean et al., 2012; Rodney et al., 2015). These studies used randomized controlled experiments that evaluated either the addition of fats (de Veth et al., 2009; Rodney et al., 2015), organic trace minerals (Rabiee et al., 2010), or protein (Lean et al., 2012) on reproductive outcomes. Few experiments have been identified that examine the effects of carbohydrate fractions on fertility, which has previously limited the ability to examine these specific dietary components using meta-analysis. Consequently, the effects of carbohydrate fractions were of interest in the current study.

The concept underpinning the current study is that reproductive failure in a group of cows is, in part, a metabolic disorder reflecting the inability of diets to supply adequate intakes, concentrations, or ratios of nutrients that are required for optimal reproductive performance. Our objective was to use carefully described dietary information from the available literature to explore the effects of the diet during the transition period on measures of pregnancy and calving to pregnancy interval as well as identifying factors that may explain variation in these responses. We hypothesized that dietary formulation and intake of nutrients during the transition period affect the probability of pregnancy to AI and interval from calving to pregnancy in dairy cows. Previous meta-analyses examining the effects of nutritional interventions during transition on reproduction identified surprisingly few papers that were suitable for inclusion (Lean et al., 2012; Rodney et al., 2015). The current study of the proportion pregnant to AI differs from previously conducted meta-analyses in that the proportion pregnant for each treatment represents a single observation, whereas previous studies have examined the difference in proportion pregnant between a reference and treatment group. The former approach allows a focus on the effects of overall diet on reproduction rather than differences between specific interventions. As such, all nutrients and potential interactions among these could be examined, irrespective of whether they were the intended intervention of a particular diet. The examination of calving to pregnancy interval used the more traditional method of using the difference between treatment and a reference group for each variable in analyses.

MATERIALS AND METHODS

Literature Search

A systematic review across 3 databases (PubMed, Web of Science CABI, and Google Scholar) and references in papers was used to identify experiments exploring nutritional interventions during transition and fertility outcomes that were published in English between 1970 and 2015 in a peer-reviewed journal, conference proceedings, or as an accepted thesis. Combinations of the following search terms were used: cow, cattle, dairy, fertility, pregnancy, conception, reproduction, b-vitamin, β-carotene, biotin, calcium, CLA, cobalt, conjugated linoleic acid, copper, cottonseed, energy, fat, fiber/fiber, manganese, magnesium, minerals, molybdenum, omega-3, organic minerals, phosphorous, protein, selenium, soy, soybean meal, vitamin A, vitamin ADE, vitamin D, vitamin E, Zinpro, and zinc. The intent of searching Zinpro was to identify studies conducted on commercial mineral mixes. Results were ordered by relevance according to the database and articles were assessed until we found 500 chronological papers that, from the title, appeared unrelated to the topic and unworthy of further review.

Inclusion and Exclusion Criteria

For clarity of reporting these results, individual nutritional treatments will be referred to as treatments and manuscripts or published papers that report one or more treatments will be referred to as experiments. For calving to pregnancy interval, the difference between 2 treatments is used and is referred to as a comparison.