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Positive consequences of maternal diet and post-natal rumen inoculation on rumen function and animal performance of Merino lambs

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A B S T R A C T

Neonatal modification of the microbial inoculum entering the gastrointestinal tract may alter the rumen microbiome and consequently alter pre- and post-weaning rumen fermentation and growth of lambs. This study aimed to determine (1) if modifying the rumen by providing ewes with lipids differing in rumen-availability in late gestation and lactation would affect performance of the lamb offspring and (2) whether cross-inoculation of neonatal lambs with digesta from sheep on an alternate diet would modify the fermentation, size, and characteristics of the developing rumen and performance of lambs. Two diets were offered ad libitum to 36 pregnant ewes (and to their lambs after lambing) from 1 month pre-lambing until 2 weeks after weaning, after which lambs were grazed in treatment groups in paddocks. Diets consisted of 92% of a blend of oaten and lucerne chopped hay, 4% molasses and 4% fat (coconut oil – CO or protected fat – PF). Newborn lambs were inoculated weekly while suckling (weeks one to eight postnatal) with fresh rumen fluid from donor ewes eating CO or PF diets, or were inoculated with water. Lamb body weight, condition score, wool growth, rumen fermentation, and rumen development were studied during the first 5 months of life of the lambs. Diet and inoculation affected dry matter intake after weaning ($P < 0.05$), being lower in lambs eating CO or inoculated with water. Feeding of CO instead of PF reduced the protozoa population and daily methane production of lambs ($P < 0.05$). Type of gut inoculum had an effect on the concentrations of acetate, propionate, butyrate, total volatile fatty acids, and total protozoa numbers in the rumen of lambs during lactation. By weaning, effects of post-natal inoculation were only apparent for the concentration of butyrate and the protozoal population. It is concluded that dietary fat can affect rumen development and fermentation of the lambs. In addition inoculation with exogenous rumen fluid can modulate some aspects of rumen fermentation. However, lamb performance evaluated at weaning and at 5 months after birth was not altered by either diet or early-life inoculum, suggesting that while the rumen microbiome may have plasticity in its composition, microbial changes do not necessarily result in improved animal performance.

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1. Introduction

The relationship between the microbes in the rumen and the host is considered a product of a symbiotic co-evolution (Ley et al., 2008; Rosenberg et al., 2010). This relationship between the ruminal microbiome and the host is related to multiple factors including: host breed (Hernandez-Sanabria et al., 2013), inoculation (Fonty et al., 1983; Dehority, 2003), age of the host (Jami et al., 2013), diet (Liu et al., 2011), early-life intervention (Leahy et al., 2013), and selection for feed conversion efficiency (Guan et al., 2008). Leahy et al. (2013) indicated that a microbial intervention early in the life of the ruminant would be the ideal opportunity to generate a lifetime effect on the host in terms of animal performance and environmental impact. Early-life intervention strategies have been studied with promising results. Yañez-Ruiz et al. (2010) changed the structure of the bacterial communities in the rumen in the medium-term (until 8 months) by changing the diet of lambs near weaning. Furthermore a recent study of Abecia et al. (2014) working with a methanogenic inhibitor in goats (kids and does) indicates scope to modify the archaeal community of the host during the development of the rumen.

The inclusion of coconut oil in the diet of ruminants has been found to generate deep changes in the fermentation and digestion of the feed, the ruminal microbial ecology, and methane production (Sutton et al., 1983; Machmüller, 2006; Liu et al., 2011; Patra and Yu, 2013; Patra, 2014). Similarly, inoculation of the rumen with microbes can improve or accelerate rumen function, rumen development, and the complexity of microbial ecology (Pounden and Hibbs, 1948; Miller et al., 1996; Krause et al., 2003; Bomba et al., 2005), as well as animal health and performance (Muscato et al., 2002), and feed conversion efficiency (Zhong et al., 2014). We reasoned that the rumen microbiome of lambs prior to weaning could be altered by post-natal intervention and as a consequence the rumen fermentation and development, and performance of the lambs both pre- and post-weaning may be modified. This article evaluates how diet (of ewe and of lamb) and how early-life inoculation with digesta from sheep on the same or on an alternate diet, affect rumen fermentation and lamb development both pre- and post-weaning.

2. Materials and methods

All research work was conducted in accordance with the University of New England Animal Ethics Committee (AEC No. 13/108) and CSIRO Animal Ethics Committee (No. 13/28).

2.1. Animals, treatments, and experimental design

Three hundred Australian Merino hogget ewes of the Elite commercial flock of Chiswick (CSIRO) were paddock-mated in May 2013, shorn in mid-pregnancy, and scanned for pregnancy by ultrasound in August. From this group 36 ewes with singleton and eight non-pregnant ewes heavier than 35.5 kg and with a condition score (CS) greater than 2.25 units (Russel et al., 1969) were selected. Criteria of selection also included the expected date for lambing in the case of singleton ewes with the objective to create a group of ewes that would lamb within a 1-week (wk) period. After selection in August, mean body weight (BW) was 39.1 ± 2.9 kg and their mean CS was 2.9 ± 0.3 units. The average expected date for lambing based on ultrasound was 21st of October ±3 days. The experiment lasted 6 months, starting (17/09/2013) 1 month before the first day of lambing (16/10/2013), continued for 5 months after lambing (17/03/2014), and had 4 stages. Stage one was from 1 month pre-lambing until lambing (involved only ewes), stage two was from lambing until weaning (ewes and lambs, 12 wk after birth), stage three lasted 2 wk after weaning (lambs only), and stage four lasted 7 wk (lambs only). Stages one, two, and three were indoors (individual pens in stage one and three, and mother-lamb in combined pens in stage two), while stage four was conducted outdoors (grazing paddocks in treatment groups).

Table 1
Chemical composition of chaff-based diets with rumen protected fat (PF; Megalac®) or with coconut oil distillate (CO).

Parameter	Diet	
	PF	CO
Neutral detergent fiber (%)	50.3	50.3
Acid detergent fiber (%)	31.3	32.0
Crude protein (%)	13.0	13.1
Dry matter digestibility (%)	56.5	56.8
Organic matter (%)	90.5	90.8
Metabolizable energy (MJ/kg DM)	9.6	9.8
Dry matter (%)	89.6	89.2

The effect of two factors, being diet and artificial inoculation of the lamb with contrasting rumen fluid, on lamb performance and rumen physiology were studied. Two different diets were fed to ewes (and lambs) from 1 month pre-lambing until 2 wk after weaning. One diet (CO) consisted of 92% of a blend of oaten and lucerne chopped hay (Manuka Feeds Pty Ltd., Quirindi, Australia), 4% molasses, and 4% distilled coconut oil, all on dry matter (DM) basis. And the second diet (PF) contained 4% Megalac® (Church and Dwight Co., Inc., Ewing, NJ, USA) instead of 4% distilled coconut oil. Formulation of the two mixed rations was based on creating iso-nitrogenous and iso-energetic diets. The most important variation between diets was the level of rumen protection of the lipids (non- and rumen-protected) and the fatty acid profile of diets, the latter explained by the inclusion of coconut oil versus protected palm oil in the diets. The protection of the lipids in Megalac® is performed with calcium (creating a calcium salt), allowing the lipids to pass unaltered through the rumen and being available and digested after the bond between calcium and lipids is broken in the abomasum at low pH (Schneider et al., 1988). Each diet was given ad libitum to half of the animals (half of pregnant ewes and later half of lambs and their dams) during all indoor stages (from 1 month pre-lambing until 2 wk post-weaning). Diets were prepared twice per wk with subsamples dried to constant weight at 60 °C for DM calculations and nutritive value analysis. Analyses were performed by the Feed Quality Service (NSW DPI, Wagga Wagga, NSW, Australia) as described by Australian Fodder Industry Association (2014) including: CP – wet chemistry AOAC method 990.03 (AOAC, 1995); ADF and NDF – AFIA methods 1.8, 1.9; digestibility – pepsin-cellulase method AFIA method 1.7R; ME – estimated from digestibility AFIA method 2.2R (Table 1). Acclimatization of the ewes to the diets was by 1 percentage unit increase in coconut oil or Megalac® inclusion every 3 days from 0% until 4% inclusion was reached.

In regards to the second factor (rumen fluid inoculation), non-pregnant ewes acclimatized to each diet were used as donors of fresh rumen fluid. Two-thirds of the lambs were inoculated with fresh rumen fluid from these ewes in a structured inoculation program. One-third was inoculated with rumen fluid from donor ewes consuming PF (this third will be named InPF), a second third of the lambs was inoculated with rumen fluid from donor ewes eating the diet CO (this third will be named InCO), and the remaining third was inoculated with MilliQ-water (will be named InW). As a result of the factorial combination of two diets (CO and PF) and three different rumen inoculums (InPF, InCO, InW), six treatments were evaluated.

During the indoor stages, the housing facility with a wood-chip floor for bedding was subdivided into two blocks of 18 pens (each pen 3.75 m^2). Ewes were penned individually before lambing, gave birth in the pen, and remained in that pen until weaning. Each treatment had six replicates, three replicates per block. In order to avoid microbial cross contamination between animals from different treatments all pens were physically isolated from each other, with each pen having two walls with clear plastic, allowing visual contact between adjacent pens but avoiding physical contact. The remaining two walls (front and back) did not have plastic on