J. Dairy Sci. 98:1–11
http://dx.doi.org/10.3168/jds.2014-9238

Colostrum quality affects immune system establishment and intestinal development of neonatal calves

M. Yang,[1] Y. Zou,[1] Z. H. Wu, S. L. Li, and Z. J. Cao[2]
State Key Laboratory of Animal Nutrition, College of Animal Science and Technology, China Agricultural University, Beijing 100193, China

ABSTRACT

The first meal of a neonatal calf after birth is crucial for survival and health. The present experiment was performed to assess the effects of colostrum quality on IgG passive transfer, immune and antioxidant status, and intestinal morphology and histology in neonatal calves. Twenty-eight Holstein neonatal male calves were used in the current study, 24 of which were assigned to 1 of 3 treatment groups: those that received colostrum (GrC), transitional milk (GrT, which was obtained after the first milking on 2–3 d after calving), and bulk tank milk (GrB) only at birth. The 4 extra neonatal calves who were not fed any milk were assigned to the control group and were killed immediately after birth to be a negative control to small intestinal morphology and histology detection. Calves in GrC gained more body weight than in GrT, whereas GrB calves lost 0.4 kg compared with the birth weight. Serum total protein, IgG, and superoxide dismutase concentrations were highest in GrC, GrT was intermediate, whereas GrB was the lowest on d 2, 3, and 7. Apparent efficiency of absorption at 48 h, serum complement 3 (C3), and complement 4 (C4) on d 2, 3, and 7 in GrB was low compared with GrC and GrT. On the contrary, malondialdehyde on d 7 increased in GrB. Calves in GrC had better villus length and width, crypt depth, villus height/crypt depth (V/C) value, and mucosal thickness in the duodenum, jejunum, and ileum, whereas GrT calves had lower villus length and width, crypt depth, and mucosal thickness than those fed colostrum. Villi of calves in GrB were nonuniform, sparse, severely atrophied, and apically abscised, and Peyer's patches and hydroncus were detected. Overall, colostrum is the best source for calves in IgG absorption, antioxidant activities, and serum growth metabolites, and promoting intestinal development. The higher quality of colostrum calves ingested, the faster immune defense mechanism and the more healthy intestinal circumstances they established.

Key words: colostrum, immunoglobulin G absorption, immune and antioxidant, intestinal development, neonatal calf

INTRODUCTION

The first milk after the cow has calved is considered the true colostrum. The subsequent 3 to 5 milk secretions are referred to as transitional milk, and afterward the cow produces whole milk. Colostrum from the first milking contains not only immunoglobulins but also considerable amounts of nutrients (Parrish et al., 1953), such as fat-soluble vitamins, vitamin B_{12}, and iron (Foley and Otterby, 1978). The colostrum quality, especially colostral total protein and immunoglobulins, decreases rapidly with the number of milkings (Parrish et al., 1948, 1950). Neonatal calves can not only acquire over 90% of nutrients during the first 2 d after birth (Parrish et al., 1953), but also absorb immune and growth factors from colostrum, such as IgA, IgM, IgG, IGF-1, lactoferrin, and lysozyme. On the other hand, colostrum is essential for passive immune transfer, promoting intestinal epithelial cell growth and differentiation (USDA, 2008), and intestinal function development in neonatal calves (Guilloteau et al., 1997; Hadorn et al., 1997). Colostrum offers the calf protection against detrimental bacteria (USDA, 2008) until its immune system and antioxidative defense mechanisms have matured. However, according to the statistics of National Dairy Heifer Evaluation Project conducted by the USDA, more than 40% of heifer calves cannot consume enough colostrum within 24 h after birth (Quigley, 2001).

To our knowledge, much literature has been published concerning the difference between either feeding colostrum or milk replacer (Seegraber and Morrill, 1986; Hammon and Blum, 1997; Rauprich et al., 2000a), but a paucity of published data is available on the difference between feeding colostrum and transitional milk

Received December 14, 2014.
Accepted April 25, 2015.
[1]These authors equally contributed to the study.
[2]Corresponding author: caozhijun@cau.edu.cn

in neonatal calves. Therefore, this investigation was performed to elucidate the effect of feeding either colostrum, transition milk, or bulk tank milk only on the day of birth on IgG absorption, immune and antioxidant status, and intestinal morphology and histology in neonatal calves.

MATERIALS AND METHODS

Animals, Treatments, and Management

Twenty-eight Holstein neonatal male calves with similar birth weight (mean ± SEM: 43.8 ± 1.5 kg) were selected from China Agricultural University's Shunyi Research Farm (Beijing, China). Twenty-four of them were randomly assigned to 1 of 3 treatment groups directly after birth: first milking colostrum (**GrC**), transitional milk (**GrT**), and bulk tank milk (**GrB**), respectively. The other 4 extra calves were assigned as a control group (**CON**) and used to compare the intestinal morphology and histology. Transitional milk was obtained after the first milking on 2 to 3 d after calving. First colostrum and transitional milk from proper dams were collected separately in plastic bottles and stored at −20°C until the day of feeding when it was thawed and warmed to 40°C before feeding (ColoQuick, Skive, Denmark). Calves received 4.0 L of the different types of milk immediately after birth and then 2.0 L at 8 h after birth. The calves received the same kind of milk twice daily at 0800 and 1700 h from d 2 in the amount of 3.5 L/meal. Calves received different types of milk (colostrum, transitional milk, or bulk tank milk) on the day of birth in the calving pen, and then were moved to individual hutch with outdoor pens on straw bedding the day after birth and housed during the experimental period. The care and feeding of calves in the experimental groups were identical from d 2. The experimental protocol was conducted in accordance with the practices outlined in the Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching (FASS, 2010). Calves suffering from diarrhea were not medicated in case of influence on antibody.

Experimental Sampling, Measurements, and Chemical Analysis

IgG in Milk. Immunoglobulin G content of colostrum, transitional milk, and bulk tank milk was determined by UV spectrophotometry (UV-2000, UNICO, Fairfield, NJ) at 340 nm according to NY/T 2070/2011.

Body Weight Measurement and Health Status. All calves in the GrC, GrT, and GrB groups were weighed on d 8 before feeding. Incidences of diarrhea and death were recorded during the experimental period.

Serum Collection and Analysis. Blood samples were taken by jugular puncture into Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ) without anticoagulant for the determination of total protein (**TP**) and IgG before receiving colostrum or milk (0 h), and then at 24 and 48 h later. Additional blood samples were taken by jugular puncture on d 1, 2, 3, and 7 of life before the morning feeding into tubes without anticoagulant for the determination of complement 3 (**C3**), complement 4 (**C4**), superoxide dismutase (**SOD**), albumin (**ALB**), malondialdehyde (**MDA**), glucagon (**GC**), and growth hormone (**GH**). Samples were centrifuged at 3,500 × *g* for 15 min at room temperature, and the supernatants (serum) were collected and frozen at −20°C until analysis.

An aliquot of serum was analyzed for TP concentrations using a portable refractometer (model WZ-312, Honneur, Beijing, China) immediately after collection on the farm. The concentrations of TP, IgG, ALB, C3, C4, and SOD were determined using the corresponding assay kits from Beijing Strong Biotechnologies Inc. (Beijing, China) in an automated biochemistry analyzer (model 7020, Hitachi, Tokyo, Japan). The GC, GH, and MDA were assayed with kits from Beijing Boruijie Technology Development Co. Ltd. (Beijing, China) in an absorbance microplate reader (EXL 800, BioTek, Winooski, VT).

Small Intestinal Morphology and Histology. Calves in CON were killed immediately after birth. On d 8 before the morning feeding, 4 calves per experimental group (GrC, GrT, GrB) were randomly chosen and killed. The calves were administrated with nembutal intramuscularly, followed by intravenous exsanguination. The intestinal tract of these calves was excised and divided into 3 segments of duodenum, jejunum, and ileum.

Approximately 2-cm lengths of the proximal duodenum, jejunum, and ileum were removed for gut morphological measurements. The gut samples were flushed with ice-cold buffered PBS at pH 7.4 and immediately placed in 4% formalin solution (Yang et al., 2007).

Three cross-sections for each intestinal segments fixed with formalin solution (total of 12 samples for each of the 3 intestinal segments per group) were prepared by paraffin embedding, and 4-μm thickness sections were cut then were stained with hematoxylin-eosin for microcopy examination under 40× magnifications (Yi et al., 2005). Approximately 15 intact, well-oriented crypt-villus units were selected in triplicate from each intestinal cross-section (45 measurements for each