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Invited review: Growth-promoting effects of colostrum in calves based on interaction with intestinal cell surface receptors and receptor-like transporters

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ABSTRACT

The postnatal development and maturation of the gastrointestinal (GI) tract of neonatal calves is crucial for their survival. Major morphological and functional changes in the calf's GI tract initiated by colostrum bioactive substances promote the establishment of intestinal digestion and absorption of food. It is generally accepted that colostrum intake provokes the maturation of organs and systems in young calves, illustrating the significance of the cow-to-calf connection at birth. These postnatal adaptive changes of the GI tissues in neonatal calves are especially induced by the action of bioactive substances such as insulin-like growth factors, hormones, or cholesterol carriers abundantly present in colostrum. These substances interact with specific cell-surface receptors or receptor-like transporters expressed in the GI wall of neonatal calves to elicit their biological effects. Therefore, the abundance and activity of cell surface receptors and receptor-like transporters binding colostral bioactive substances are a key aspect determining the effects of the cow-to-calf connection at birth. The present review compiles the information describing the effects of colostrum feeding on selected serum metabolic and endocrine traits in neonatal calves. In this context, the current paper discusses specifically the consequences of colostrum feeding on the GI expression and activity of cell-receptors and receptor-like transporters binding growth hormone, insulin-like growth factors, insulin, or cholesterol acceptors in neonatal calves.

Key words: cow-to-calf connection, digestive tract, mammary gland, perinatal period, cell surface receptor

INTRODUCTION

The Cow-to-Calf Connection for the Postnatal Development of Calves

After birth, the transfer of nutrients from mother to fetus ceases and the neonate must orally ingest nutrients and digest them. Colostrum is typically the first food ingested by the calf. Thus, colostrum intake exposes the gastrointestinal (**GI**) tract of neonatal calves to nutrients (e.g., fat, lactose) and various bioactive substances such as immunoglobulins, IGF, insulin, or cholesterol (Table 1; Koldovský, 1989). Bioactive substances found in mammary secretions elicit their biological effects directly on the wall of the calf's GI tract, are first transported across intestine into the calf's circulation, or both. These substances are either locally synthesized in maternal mammary tissues, are transferred from blood circulation by various mechanisms, or both (Baumrucker and Albrecht, 2014; Baumrucker and Bruckmaier, 2014). The transfer of some bioactive substances present in colostrum is mediated by cell surface receptors and receptor-like transporters located within the calf GI tract (Baumrucker and Albrecht, 2014; Ontsouka and Albrecht, 2014). For example, the transport of IgG_1 from maternal blood circulation into colostrum is mediated by neonatal Fc receptor (**FcRn**), whereas that of cholesterol is thought to involve ATP-binding cassette (**ABC**) transporters of classes A and G (Mayer et al., 2005; Lu et al., 2007; Mani et al., 2009, 2010). Other additional transporters are also involved in cholesterol transport. They include, for instance, the scavenger receptor (SR)-B1 (Truong et al., 2010; Ji et al., 2011), the Niemann Pick C1-like protein 1 (**NPC1L1**; Altmann et al., 2004; Davis et al., 2004), and NPC1 (Mani et al., 2009) whose transport mechanisms, however, are not a focus of the current review.

Bioactive substances in colostrum have beneficial effects on morphological growth and functional maturation of the GI tract as well as on the metabolic, en-

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Table 1. Selected constituents of colostrum milked on d 1, 2, and 3 after parturition fed to calves[1,2]

Trait	Milking 1 (first colostrum)	Milking 3 (transition milk)	Milking 5 (mature milk)
DM, g/kg	240	165	157
Gross energy, MJ/kg of DM	24.9	24.1	22.3
CP, g/kg of DM	555	468	345
Crude fat, g/kg of DM	265	263	197
Nitrogen-free extract,[3] g/kg of DM	104	226	402
Crude ash, g/kg of DM	75	45	55

[1]Colostrum fed on d 1 to 4 of life was derived from pooled milkings 1, 3, and 5 (d 1, 2, and 3 of lactation, respectively) from about 70 dairy cows.

[2]Data shown are from Sauter et al. (2004).

[3]The nitrogen-free extract was calculated as 100 − % (moisture + CP + lipid + ash).

docrine, and health status in neonatal calves (Buhler et al., 1998; Blattler et al., 2001; Blum, 2006). An important feature characterizing the maturation of the GI tract in neonatal calves fed with colostrum is the replacement of vacuolated fetal-like intestinal epithelium present at birth by mature intestinal epithelium containing polarized enterocytes (Bittrich et al., 2004). The morphological modification of the calf's intestinal epithelium happens within a few days after birth and corresponds to a so-called gut closure. The vacuolated fetal-like epithelial cells are permeable to colostral macromolecules such as IgG_1, whose transfer into the circulation is determinant for the survival of neonatal calves. The timing of the gut closure for macromolecules is possibly influenced by some colostral factors or mechanisms that prevent excessive macromolecular absorption (Vukavić, 1984; Jochims et al., 1994).

Key characteristics of the maturation of the GI tract in neonatal calves include the establishment of new digestive and absorptive capabilities, which are undeveloped at birth. An example includes the ability to digest milk lactose (Bird et al., 1996; Ontsouka et al., 2004c; Steinhoff-Wagner et al., 2014). The above-mentioned adaptive changes and benefits associated with colostrum feeding demonstrate the relevance of the cow-to-calf connection for the successful extra-uterine life in neonatal calves.

Content of Selected Bioactive Substances in Bovine Blood and Mammary Secretions

Many bioactive substances are transferred from the blood of dairy cows into mammary secretions (in particular colostrum). Concentrations of numerous of these (e.g., IgG_1, cholesterol, growth hormone (**GH**), IGF-1, or insulin) vary during the perinatal period in mammary secretions and blood.

Considering the importance of blood for milk secretions, it should be noted that the total blood volumes in dairy cows show wide variations within, and are different between developmental or physiological stages (Turner and Herman, 1931 and Table 2). A positive relationship between blood volume and an increase in BW and age of dairy cattle has been shown. In addition, an average total blood volume of 45 L (corresponding to 77.5 mL per kilogram of BW) was found in lactating dairy cows, whereas corresponding values for nonlactating dairy cows were of 34 L and 61 mL per kilogram of BW (Turner and Herman, 1931).

IgG_1, Cholesterol, and Its Derivatives. Blood serum IgG_1 concentrations of 9.8 to 11.8 mg/mL were observed during the early dry period followed by a decline (5.3 and 9.3 mg/mL) at parturition (Murphy et al., 2005; Table 2). During lactation, serum IgG_1 oscillated between 10 and 12.4 mg/mL in dairy cows (Murphy et al., 2005; Table 2). Concerning the content of IgG_1 in milk secretion, significant amounts are transferred from blood into colostrum. The IgG_1 concentrations in colostrum were reported to vary between 75 and 96 mg/mL (Murphy et al., 2005; Table 2).

Cholesterol requirements by mammary gland tissues, respectively, by mammary epithelial cells or mammary adipocytes, increase with the onset of lactation (Mani et al., 2010). The circulating cholesterol consists of fractions bound to carrier lipoproteins, namely chylomicrons, very low-density lipoproteins, low-density lipoproteins, and high-density lipoproteins, whose major constituent is apolipoprotein (**apo**) A-1. The content of blood serum total cholesterol is high during the dry period (~2,320 mg/L) and declines to approximately 389 to 1,159 mg/L in early lactation (Table 2). Blood serum cholesterol levels steadily increase during lactation to values ranging from 2,319 to 2,706 mg/L in late lactation (Mohebbi-Fani et al., 2006; Mani et al., 2009; Table 2). Cholesterol is a component of milk and is higher in colostrum than in mature milk (Shope and Gowen, 1928, Table 2). The reported concentrations of cholesterol in colostrum 24 h after parturition are be-