Ultrasonographic measurement of abomasal volume in calves after administering 4 liters colostrum through tube feeding

Figure 1: Tube feeding calves (1).

Research Project Veterinary Medicine Utrecht University

E. Hamersma, BSc
Studentnr. 3174387

September-December 2011

Supervisor:
R. Jorritsma, DVM, PhD, MSc
Department of Farm Animal Health, Faculty of Veterinary Medicine, Utrecht University.

INDEX

SUMMARY

Aim of this study was to determine which amount of 4 liters colostrum administered to newborn calves by esophageal drenchers would enter the abomasum. This feeding strategy is used to provide calves sufficient amounts of immunoglobulins, in order to prevent failure of transfer of passive immunity (FTPI). To newborn calves (n = 4) 4 liters colostrum was administered by an esophageal drencher, within 2 hours after birth. Abomasal volume was determined using ultrasonography. Mean determined abomasal volume was 2.74 liters (CI 1.87 – 3.61). No correlation (- 0.134) was found between determined abomasal volume and administered volume. Determined abomasal volume was significantly different from administered volume (p = 0.025). In another newborn calf 2.1 liters of a solution of colostrum and barium-sulfate was provided by an esophageal drencher. X-rays and fluoroscopy was performed to determine localization of provided colostrum. Fluoroscopy showed a first entry of colostrum into reticulum and ruminal atrium, after which overflow to all ruminal compartments, omasum and abomasum occurs. No flow into duodenum was detected. This study clearly shows that the abomasum is unable to contain 4 liters colostrum. Also, this study shows colostrum is localized in all parts of the forestomachs and abomasum. Further research should be conducted to determine other effects of this feeding strategy applied on newborn calves.

INTRODUCTION

Early and adequate intake of good quality colostrum, has a major influence on health of newborn calves. Colostrum consists of several important components, such as proteins, vitamins, minerals, maternal leucocytes, cytokines, growth factors and immunoglobulins (IgG, IgA and IgM), which contribute to the survival of the calf in its first days of life (2-6).

A cow has a syndesmochorial placenta which prevents transmission of immunoglobulins from dam to the fetus in utero (7,8). Thus, a calf is born hypoglobulinemic and is dependent on immunoglobulins provided by colostrum. It is recommended to feed the calf colostrum as soon as possible after birth (within 2 hours) as the calf than has an “open gut”. This term refers to the ability of the intestinal tract to take up large components from the intestinal lumen and lasts until so called “gut closure” approximately 24-36 hours after birth (3,6)

Failure of transfer of passive immunity (FTPI) is a term commonly used in literature to describe the insufficient uptake of immunoglobulins after birth, measured as a decreased plasma concentration of immunoglobulins. A generally accepted benchmark to avoid FTPI is set at 10 g/L or 6.0 g/L IgG in serum 24-48 h postnatal (5,9-11).

Failure of transfer of passive immunity has been related to high mortality, especially if IgG concentration in serum is less than 5 g/l. In a study to the relationship between calf mortality and inadequate passive transfer, Tyler et al (1999) calculated that 39% of the calf mortality was due to inadequate transfer of passive immunity (10). Based on a longitudinal study, Donovan et al. (1998) concluded that mortality rate and

FTPI were correlated and he concluded that FTPI was a significant risk factor for occurrence, age of onset and severity of septicemia and pneumonia (11). Other studies reported that a correlation with daily gain and milk production has also been found (12).

Occurrence of FTPI or insufficient IgG uptake could be due to feeding too low quantities of colostrum or by using colostrum with a low concentration of IgG. As quality of colostrum is quite variable and generally not tested, volumes are usually not adjusted in case of low colostral quality, e.g. below the minimum standard of 50 g/L. (2,4-6,13).

In order to assure that a sufficient amount of IgG are provided, researchers have calculated which amount of colostrum needs to be provided to compensate possible shortcomings in colostrum quality. Focusing on the critical mass of provided immunoglobulins Davis et al. (1998) determined that the critical mass of IgG that needs to be administered to newborn calves is 100 g in the first colostrum feeding (2,5,6,14). Chigerwe et al. (2008) concluded recently that this amount is insufficient to achieve adequate passive transfer and suggested that at least 150-200 g IgG's should be administered to achieve a proper transfer of passive immunity (13,14). To achieve this, it is currently advised to give newborn calves 4 liters of colostrum within 2 hours. Because a calf does not consume such an amount of colostrum voluntarily, it is recommended to feed the colostrum with an esophageal drencher (2,3,5,9,13). Other authors stated that 4 liters of colostrum should be divided in two portions of 2 liters each and fed within 12 hours postnatal and recommended the use of a drencher only when calves are too weak or do not drink voluntarily (15).

There is no quantitative research on the maximal volume of milk that can be provided to newborn calves given the limited volume of the abomasum. Chapman et al (1986) reported a failure of the reticular groove reflex when an esophageal drench was used. This resulted in a leakage of fluid to the reticulorumen, overflow to the abomasum occurred when over 400 mL had been given. However, instead of using colostrum, Chapman et al (1986) used a liquid solution consisting of glucose, electrolytes and amino acids and a solution of $BaSO_4$. Also the amount of liquid administered was significantly lower than the amount of liquid administered in this study (16).

Especially in Europe still some concern exists whether the failure of the esophageal groove reflex may cause detrimental effects on calf health (12). Previous research has shown that a failure of the groove reflex causes deposition of milk in the rumen. Fermentation of this milk leads to the syndrome of ruminal drinkers, which is characterized by apathy, inappetence, abdominal distension, decreased growth rate, a long, dry haircoat and sticky clay-like faeces. However, this syndrome is described for calves aged from 4 weeks (17,18).

Development of ruminal microbial environment takes places directly after birth (19). Presence of microbial environment in newborn calves is low at birth and decreases the risk for ruminal drinkers syndrome.

It is possible that ruminal and intestinal microbial development is disturbed, when colostrum localizes on other places than the abomasum. In order to confirm this, research to abomasal volume is necessary.

Because a newborn calf does not voluntarily consume more than 2.5 liters of colostrum, it can be assumed that the abomasum of a newborn calf has maximal volume of 2.5 liters (2,3,5). Godden estimates that the volume of the reticulorumen of a Holstein Frisian calf weighing 50 kg is approximately 1 liter (unpublished observation) (9). Summarized, the location of 3.5 liters colostrum can be predicted and a volume of 0.5 liter colostrum must be located elsewhere, when 4 liters colostrum is administered.

Apart from the positive functional aspects of drenching calves with 4 liters of colostrum by oesophageal tubing on plasma immunoglobulins, the consequent application of this strategy has resulted in criticism form a welfare point of view (20). It can be suggested that increasing the number of feedings to achieve a total uptake of 4 liters is preferred from a welfare point of view, while the effects of large volumes of colostrum due to the provision of 4 liters at once may have detrimental effects on e.g. microbial development of rumen and gut flora. Those effects are still unknown.

Objective of this study was therefore to examine which amount of the colostrum administered by an esophageal drench enters the abomasum. In order to measure the volume of the abomasum, a technique (slightly modified) described by Wittek et al (2005) was used. Also, radiology and fluoroscopy were used to determine the localization of the provided colostrum.

MATERIALS AND METHODS

ANIMALS

This study was approved by the Dutch Animal Experimentation Ethical Committee (DEC) under number 2011.III.09.094. For the first experiment, 3 healthy Holstein Frisian calves and 1 Belgian Blue-Holstein Frisian calf were used in this study, with a mean body weight at birth of 44 ± 2.8 kg. In the second experiment, 1 Holstein Frisian calf was used, with a body weight at birth of 32 kg. These calves were obtained from dairy cows housed at the farm animal health department, Faculty of Veterinary Medicine, Utrecht University. Calves were born spontaneously or by caesarian section. At birth, calves were weighted and housed in individual pens bedded with straw.

EXPERIMENT (1)

Newborn calves (n = 4) were fed 4 liters of colostrum with an esophageal tube feeder (Ritchey calf feeder) within 2 hours after birth. Colostrum was derived directly from the dam if possible, otherwise frozen colostrum from another cow was thawed using warm water (water temperature <60 °C). Temperature of fed colostrum was between 37 °C and 40 °C. Colostral quality was not always determined. The size of the abomasum was determined using ultrasound (21). Feeding 4 liters of colostrum by esophageal tube feeder required 2 minutes and ultrasonigraphic measurements were obtained within 5 minutes after administering colostrum. All measurements were performed by the same investigator.

Each calf was gently fixated in standing position. To determine abomasal volume, a technique was used, described by Wittek et al. (2005) (21). Some modifications to the technique were made. Shaving the ventral abdomen of calves was not possible, because calves were partially wet from amnion fluid. Instead of shaving, paraffin was used to create a proper ultrasonographic view. For ultrasonography the MyLab™30 VET (esaote) was used, with preset canine abdomen, depth was adjusted manually when necessary (22). A combination of the linear array probe (10-5 MHz) and the sector probe (3.5-MHz) were used (22). Length was determined with linear array probe, width and height with sector probe. Length was determined by measuring both the distance between the xiphoid process and the cranial margin of the abomasum as the distance between the xiphoid process and the caudal margin of the abomasum. Total abomasal length was calculated by subtraction of these two values. Both for height and width, images as well as short clips were taken with the sector probe and determined by using the measurement options of the MyLab™30 VET. To make sure the values for width and height were correct, widest and highest point of the abomasum were ultrasonographic determined by making several images as well as short clips.

After gathering the appropriate distances, abomasal volume was calculated. Because the abomasum of the calf has an ellipsoid shape after suckling, an equation for calculating the volume of an ellipsoid was used (ie, volume = width X length X height X $\pi/6$, where the constant π is an irrational number [approximately 3,142]) (21).

EXPERIMENT (2)

Experiment was done within 2 hours after birth. Colostrum was mixed with a barium-sulfate solution, by an experienced radiologist. Calf was fixated in standing position. After taking a native X-ray of the left lateral abdominal region, 3.2 liters colostrum solution (10 % BW) was administered using an esophageal drencher. During administering fluoroscopy of the left lateral abdominal region was performed. Records of fluoroscopy were taped and stored on videotape. After administering colostrum, another X-ray of the left lateral abdominal region was taken.

STATISTICAL ANALYSES

A statistical software program, SPSS 20, was used for all statistical analyses. Student's T-test was used to calculate mean, standard deviation and confidence interval. Paired sample T-test was used to compute the differences between administered and determined abomasal volume. A P-value of 0.05 was considered as significant.

RESULTS

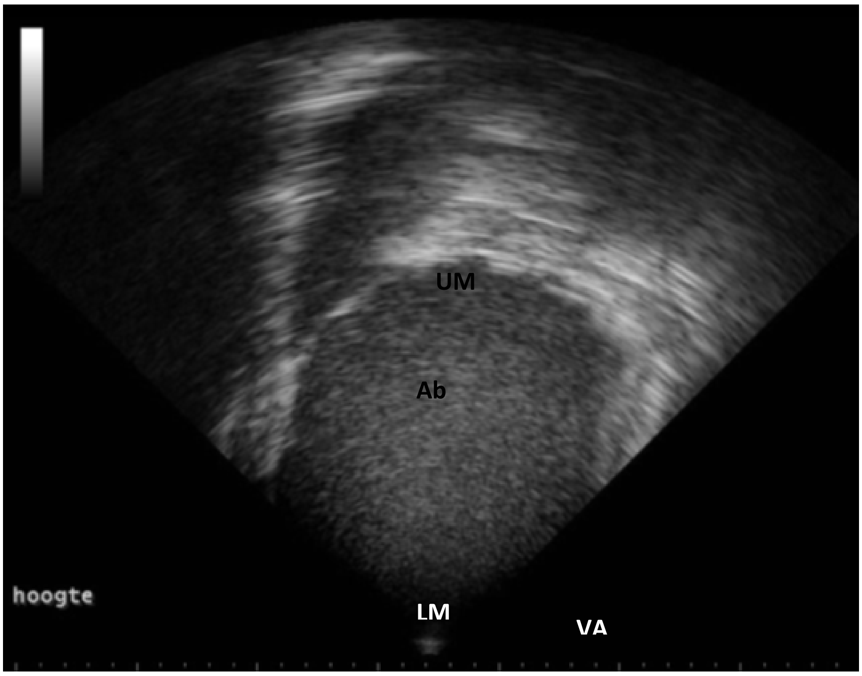

Figure 2: Ultrasonographic image of abomasum, preset: Canine A PA230, Depth: 27 cm. Ventral measurement of abomasal height. Ab: abomasum, LM: lower margin abomasal height, UM: upper margin abomasal height, VA: ventral abdominal wall.

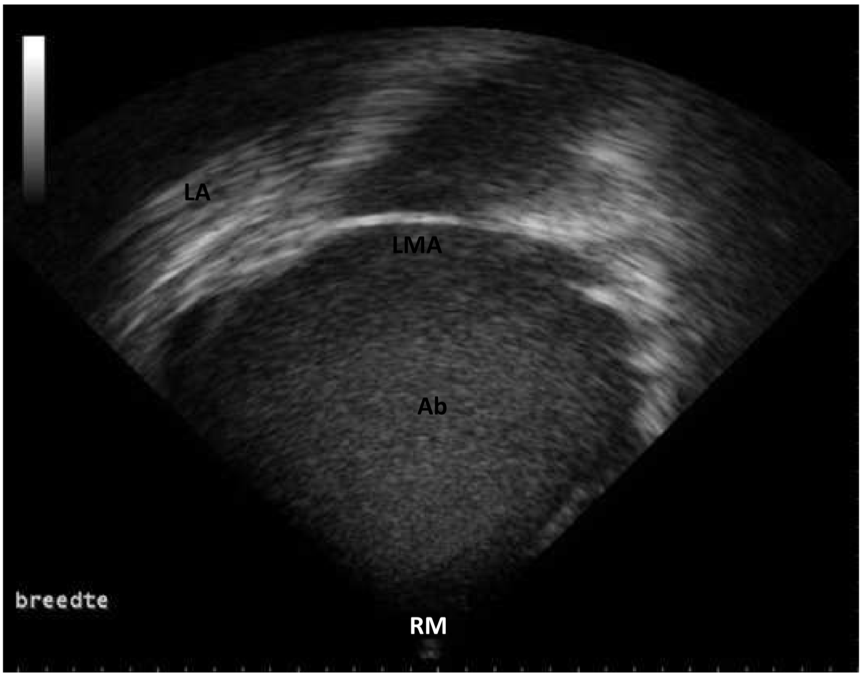

Figure 3: Ultrasonographic image of abomasum, preset: Canine A PA230, Depth: 23 cm. Right lateral measurement of abomasal width. Ab: abomasum, LMA: left margin of abomasum, LA: left lateral abdominal wall, RM: right margin of abomasum.

EXPERIMENT 1

Images of ultrasonography of calves (n=4) were examined and abomasal dimensions were determined (figure 2-4). Calculated abomasal volume after administering 4 liters of colostrum using esophageal drencher ranged from 2.04 to 3.37 L and was on average 2.74 L (CI 1.87-3.61 L). Mean administered volume was 3.91 ± 0.075 L (CI: 3.79-4.03 L). Determined abomasal volume was significantly different (P = 0.025) from administered volume, average difference was 1.17 L (CI: 0.27-2.06 L). No correlation (- 0.134) was found between administered and determined abomasal volume.

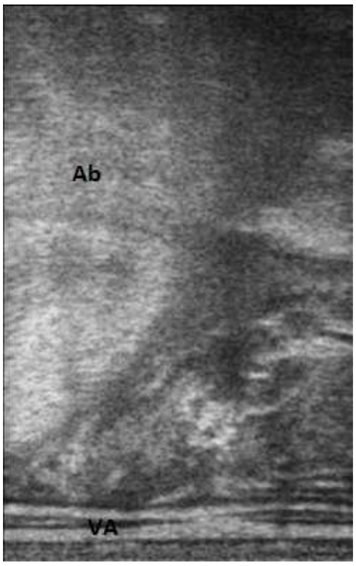

Figure 4: Ultrasonographic image of abomasum, preset: Canine A LV513, Depth: 8 cm. Ventral measurement of abomasal length, image shows caudal margin of the abomasum. Ab: abomasum VA: ventral abdominal wall.

EXPERIMENT 2

No signs of abdominal abnormalities were visible on the native X-ray of left lateral abdominal region. Forestomachs and abomasum were filled with fluid (figure 5). Fluoroscopy showed an entry of the first amount of colostrum in the reticulum and ruminal atrium. When reticulum and rumenal atrium were filled, overflow to all other ruminal compartments, omasum and abomasum occurred. During filling the abomasum increased evidently and gradually expanded over the ventral abdominal wall (figure 7 and 8). After 2.1 liters no flow into calf was possible and the decision was made to stop the administering of colostrum. X-ray after administering colostrum showed an increased volume of the stomach-complex compared to native X-ray. Filling of reticulum, rumen and abomasum was clearly visible (figure 6). No flow of colostrum into the duodenum was detected.

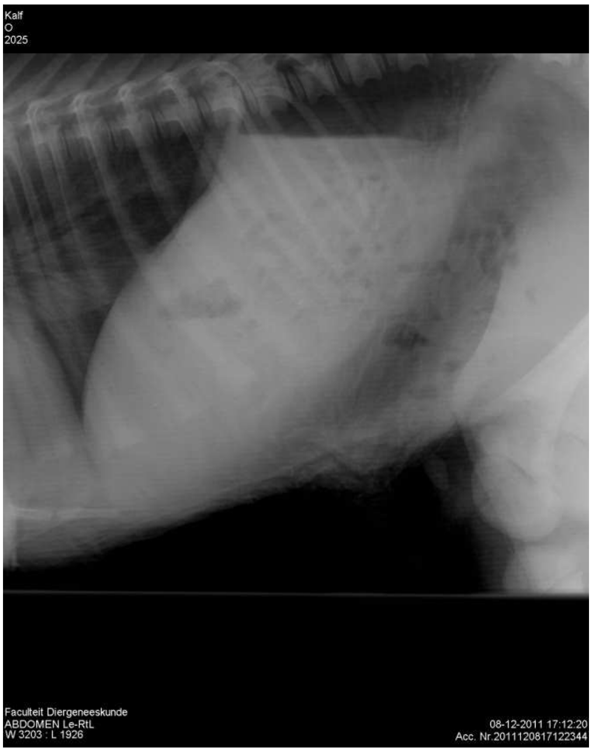

Figure 5: Native X-ray of left lateral abdominal region calf. Forestomachs and abomasum are filled with fluid.

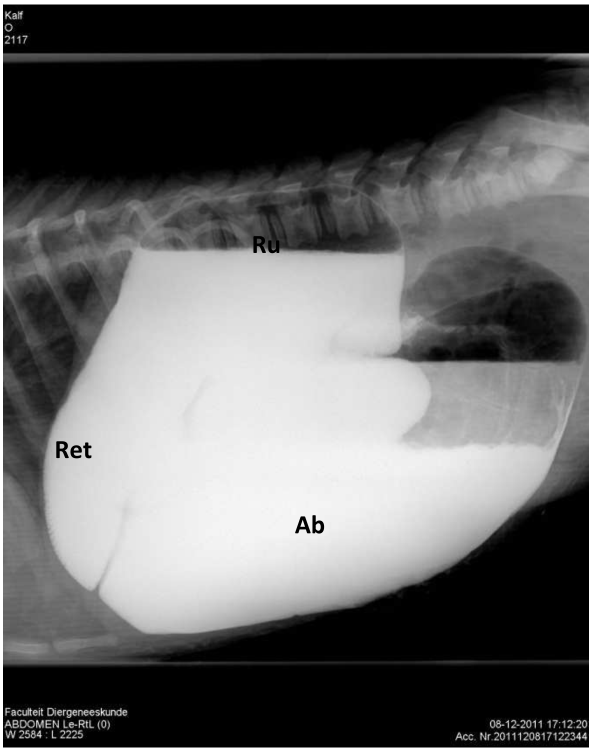

Figure 6: X-ray left abdominal region calf, after administering 2.1 liters of colostrum and barium-sulfate solution. Forestomachsand abomasum filled with solution of colostrum and barium-sulfate. Reticulum (Ret), rumen (Ru) and abomasum (Ab) can be distinguished.

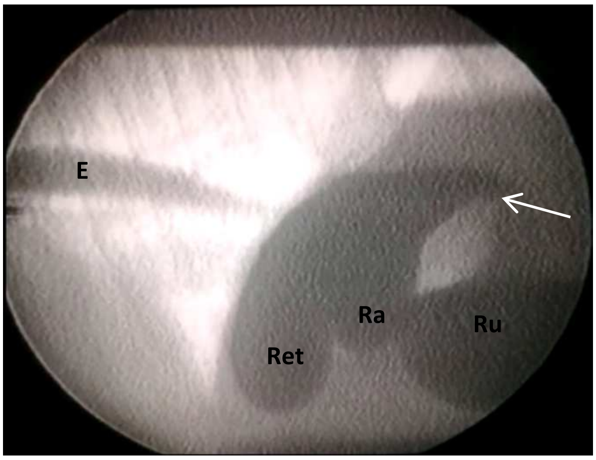

Figure 7: Fluoroscopic image of left abdominal region calf. Overflow to ruminal compartments is visible (arrow). E: esophagus, Ra: ruminal atrium, Ret: reticulum, Ru: rumen.

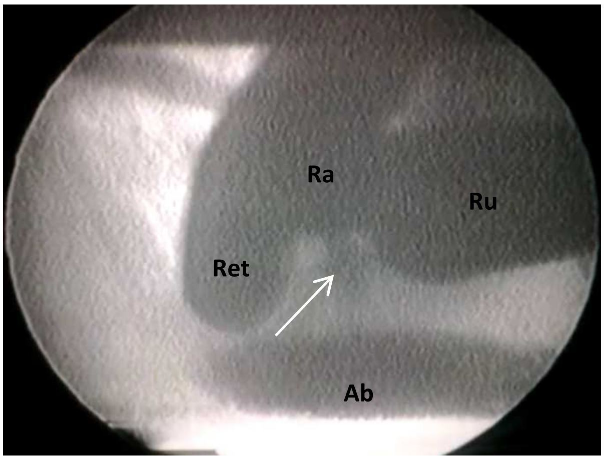

Figure 8: Fluoroscopic image of left abdominal region calf. Overflow to abomasum is visible (arrow). Ab: abomasum, E: esophagus, Ra: ruminal atrium, Ret: reticulum, Ru: rumen.

DISCUSSION AND CONCLUSION

This study clearly shows that the abomasum is unable to contain 4 liters of colostrum. Mean abomasal size was determined on 2.74 L (95% CI 1.87-3.61) and a significant difference between administered volume and determined abomasal volume was measured. Because of the small sample size, confidence interval was relatively wide. Nevertheless, despite this wideness, the interval did not contain 4 liters or more. After administering 4 liters, small amounts of colostrum remained inside the drencher. Remaining volume was measured after finishing the measurements. This resulted in variation in administered amount of colostrum. Even though this created a wider confidence interval, both intervals did not overlap.

Godden et al. (2008) and McGuirk et al. (2004) stated that a newborn calf normally does not voluntarily consume more than 2.5 liters (2,3,5). This has led to the assumption that the abomasum has a maximal volume of 2.5 liters. During the study abomasal volumes larger than 2.5 liters were found. The largest abomasal volume measured was ± 3.37 and mean volume was 2.74 liters. Both are larger than the expected maximal volume. It seems that the motivation to drink colostrum does not depend on maximal abomasal volume.

We determined abomasal length using a linear probe. The tip of the probe consists of a part which gives no image. This part is approximately 8 mm long and we did not correct for this during the measurements. This has resulted in a slight over-estimation of abomasal volume and therefore strengthens our finding that the provided 4.0 liters would not fit in the abomasum. For abomasal height and width, probes were held perpendicular to the abdominal wall. Slight inaccuracies in the position of the probe may again have resulted in a slight over-estimation of the abomasal volume. Our measurements of the abomasal volume therefore represent the upper values of abomasal volume rather than the lower volume. Our conclusions therefore likely underestimate the real difference between abomasal volume and supplemented amount of colostrum.

Due to the small sample size no correlations were found between administered volume, abomasal volume, gender, body weight at birth and way of birth. It is likely that a heavier calf has a larger abomasal volume. In this study 2 calves of 42 kg had a determined abomasal volume of respectively 2.04 liters and 3.37 liters, which implies, that a correlation is not likely between body weight at birth and abomasal volume. However further research is necessary to confirm this implication.

During echography a fluid filled structure was sometimes visible on the left side of the calf. This structure was situated dorsal to the abomasum. After collection of the necessary data, this structure was further investigated. Based on literature and location this structure seems to be the reticulum. This confirms that the reticular groove reflex is not functioning using a drencher.

By administering 4.0 liters of colostrum it can be assumed that abdominal volume increases and this might influence respiration, because an increased abdominal volume may prevent contraction of the diaphragm. However, during this study no clinical problems were observed and no measurements were done in relation to respiration. Further research should confirm this hypothesis.

Fluoroscopy confirms that reticular groove reflex does not function when esophageal drenchers are used. As a result of this failure, colostrum flows into the reticulorumen and omasum before entering the abomasum. Fluoroscopy also showed a substantial increase of abomasal dimensions. However, calf used in this experiment had relatively low body weight at birth (32 kg) and though vitality was excellent, this calf may not be representative for the population. Also sample size (n = 1) in experiment 2 was clearly minimal.

We decided to stop feeding (experiment 2) after administered 2.1 liters of colostrum, because flow of colostrum into the calf did not further occurred. This may be due to the size of the abomasum, low body weight or the position of the drencher. Nevertheless, fluoroscopy confirmed that large amounts of colostrum administered with esophageal drencher do not fit in abomasum solely.

X-ray after administering colostrum showed an evident increased abdominal volume (figure 6), it can be assumed that increased abdominal volume influence animal welfare. Although no problems after administering 4 liters with a drencher were observed, some concern remains about the welfare of those calves. Especially as attention for animal welfare is increasing, it is necessary to look critically at modern husbandry and to the applied methods used by producers. Feeding 4 liters colostrum in the first meal is required because colostrum quality is unknown for producers. However, determining quality of colostrum is relatively easy, when a colostrometer is used. If colostrum is of high quality, amount of colostrum necessary in the first meal can be reduced. Poor quality colostrum should not be used. The use of a drencher and 4 liters colostrum obscures a poor colostrum management.

This study shows clearly that colostrum is localized in all parts of the forestomachs and the abomasum after administering 4 liters of colostrum and that abomasal size varies from 1.87 to 3.61 liters. Effects of colostrum in the rumen almost immediately after birth should be further investigated. Colostrum might have effects on ruminal development or cause some damage in reticulorumen. Another important effect of 4 liters colostrum in newborn calf may be the influence of abdominal volume on respiratory ability. Therefore, it is possible that the use of an esophageal drencher should not be recommended to hypoxic calves. However, to confirm this possible effect, further research is necessary.

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