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Failure of passive transfer in neonatal calves in dairy farms in Ankara region

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Abstract: This study, as a model for the farms in Turkey implementing professional herd management protocols, was conducted to examine a variety of factors in relation to the prevalence of failure of passive transfer (FPT) and the passive transfer (PT) in dairy farms in Ankara. A total of 400 calves and 363 cows from 9 different farms practicing professional herd management systems and employ full-time veterinarians were included in the study. Following the birth of the calf, colostrum was taken from cows, blood samples were taken from calves at 24–48 h of age and analysed for IgG using ELISA. FPT was determined in 69 (17.25%) of 400 calves examined and 44 (12.12%) of 363 cows produced insufficient quality colostrum (IgG concentration < 50 mg/mL). The average blood IgG concentration of calves was 14.16 mg/mL, and the average colostrum IgG concentration was 90.41 mg/mL. When various data related to FPT are evaluated, the risk of FPT increases 15.4 times in calves fed with insufficient quality colostrum, and the risk of overcoming diseases in calves with FPT increases 1.6 times until weaning. In conclusion, the FPT rate was around 20% in dairy farms in Ankara, where advanced herd management techniques were practiced and still pose a serious risk.

Key words: IgG, failure of passive transfer, disease, dairy calf

1. Introduction

Due to syndesmochorial placentation, cows are not able to transfer macromolecular antibodies and many components to their offspring during pregnancy therefore calves are born agammaglobulinemic and colostrum is the only source of passive immunity [1,2]. A successful passive immune transfer is achieved by taking Ig-rich colostrum within the first hours of birth [3]. When evaluating the success of the passive immune transfer, IgG, which alone constitutes 85%–90% of colostral immunoglobulins is taken as the basis [4]. In a successful passive transfer, the calf is expected to have serum IgG above 10 mg/mL within 24–48 h following colostrum intake [5]. In order to achieve sufficient IgG passive transfer, it is very important that colostrum is given in a timely manner, in sufficient quantity, and most importantly quality. These 3 main determinants affecting passive transfer are known as the 3Q rule (quantity, quality, and quickly) [6]. It is desirable that colostrum, has an IgG concentration of 50 mg/mL or above [7]. Colostrum quality is measured by the concentration of colostral Igs contained, and the amount of colostral Ig differ depending on many variables such as breed, amount of colostrum produced at first milking and total colostrum volume secreted, calving season, maternal age, maternal illnesses, prepartum feeding and dry period, vaccines and drugs used, prenatal colostrum leakage from the breast and the time between birth and first milking [8,9].

Failure of passive transfer (FPT) is not a disease, but a condition of immunodeficiency that predisposes the calf to diseases [9]. In cases where calf deaths are 5% or less, passive immunity is considered successful [10]. Besides FPT is one of the biggest causes of calf deaths, nonimmunoglobulin factors in colostrum can also cause serious productivity losses due to insufficient transfer to the systemic circulation. Studies have reported that in calves with FPT, live weight gain and decrease in feed utilization lead to a shift in the first calving age and low milk yield in the first 2 lactations [4,11].

It has been reported that the prevalence of FPT may be quite high, despite the careful implementation of advanced herd management protocols [4]. Researchers have reported that FPT can be above 25% even in well-managed farms [3,5].

In our country, dairy cattle husbandry can be defined in 3 groups; small family farms with a small number of cattle and usually practicing traditional husbandry methods, medium-sized enterprises with a manageable

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number of cattle and made some progress in modern husbandry methods and professional farms with a large number of cattle and implementing professional herd management protocols such as separate parturition lounge, milking parlours, pasture, and most importantly, newborn protocols are applied consciously and there is intensive production. This study was aimed to determine the prevalence of FPT in 400 calves and their mothers on 9 professional dairy farms in Ankara as a model and to examine the effects of the factors affecting FPT in this production system.

2. Materials and methods

This study was carried out with the approval of Ankara University Animal Experiments Local Ethics Committee, decision number 2018-1-1.

2.1. Animals

The material of this study consisted of cattle and calves raised on 9 dairy farms in Ankara. Criteria used in determining farms were as follows; applying professional management practices such as the presence of at least 100 cows or more, practicing intensive breeding, predetermined ratio according to the needs of the animals, using infrastructure such as a milking unit, birth box, calf shed, employing a full-time veterinarian or veterinary health technician, programmed preventive veterinary practices. Cattle breeds were Holstein–Friesian on 5 farms, Simmental on 1, Swiss Brown on 1, and mix of aforementioned breeds on 2. The number of animals included was proportional to the number of cows raised on the farms. The number of cows raised on the farms and neonatal calves sampled is given in Table 1. A total of 400 calves were included in the study; 281 Holstein, 55 Swiss Brown, and 64 Simmental. A prestructured form was used to collect information about the farm's demography and management practices.

2.2. Collection, transport and storage of serum and colostrum samples

Calves were given different amounts of colostrum within the first 4 h of life. Four hundred calf sera were collected for the study, but 363 colostrum samples were included in the study since colostrum could not be collected from farm number 5. A total of 363 first milking colostrum samples were taken from the teat within the first 4 h after birth and they were stored at –20 °C until analyses. Blood samples were taken from all calves within 24–48 h after the first feeding. Serum was harvested and stored at –20 °C until analyses.

2.3. Collection of information about management practices

A prestructured form was distributed to all farms and veterinarians were requested to fill in. The forms were kept at the farm until calves were weaned. At the end of the study, all forms were collected from the farms. The forms included information on dam and calf; dam's ear tag, breed, any vaccination during pregnancy, dry period, any diseases during the last 3 months of pregnancy, dystocia, lactation and any sort of transportation of dam, and amount of colostrum produced in the first 2 milking after birth, calf's; ear tag number, sex, birth weight, twinning, amount of colostrum intake, method of colostrum administration, hyper immune serum application, use of colostrum substitute feed, use of any product containing IgG, weaning age, weaning weight, diseases noted until weaning and other conditions reported.

Staff of all the farms studied were asked to fill in this information and some data that could not be obtained for

Table 1. Number of calves sampled and FPT ratios between farms.

	Number of cattle	Number of samples	Number of calves with FPT	FPT %
Farm 1	800	110	26	23.64%
Farm 2	600	82	15	18.29%
Farm 3	320	48	0	0.00%
Farm 4	270	40	3	7.5%
Farm 5	240	37	10	27.03%
Farm 6	130	20	2	10.00%
Farm 7	110	32	7	21.88%
Farm 8	110	16	3	18.75%
Farm 9	100	15	3	20.00%
Grand total	2680	400	69	17.25%

FPT: failure of passive transfer.

various reasons were not taken into consideration, and the available data were evaluated within themselves. For example, birth weight of 228 out of 400 calves was recorded and these calves were evaluated. Similarly, colostrum evaluation was made for 363 colostrum samples, since farm number 5 could not collect colostrum samples.

Groupings were made based on similar studies, according to the birth weight of the calves, the amount of colostrum taken or the amount of colostral IgG. For example, 30–40 kg was determined as the average birth weight; below these values constituted the low birth weight group, and above it constituted the high birth weight group.

2.4. Analysis of serum IgG and colostrum IgG levels

Analyses were performed using a commercial enzyme-linked immunosorbent assay (ELISA) kit (Bovine Immunoglobulin ELISA kit, Bio-X Diagnostics, Rochefort, Belgium) at the Ankara University Faculty of Veterinary Medicine, Department of Biochemistry.

2.5. Statistical analysis

All data were examined by Shapiro–Wilk test in terms of normality and Levene's test in terms of homogenity of variances before starting significance tests. In examining the effects of maternal age, breed, vaccination during pregnancy, the period without lactation, disease status in the last 3 months of pregnancy, multiple births (twin), transport, difficult birth and colostrum amount in the first 2 milking on colostrum quality were examined using logistic regression. In examining the effects of a difficult birth phenomenon, colostrum quality, calf sex, calf birth weight, multiple births, colostrum first administration Ig rich serum administration, weaning age, weaning weight, and diseases encountered on passive transfer failure were also investigated using logistic regression. The variables of maternal age, dry period length, birth weight, amount of first colostrum administration, time of first colostrum administration, weaning age and weaning weight were included as continuous variables in the model. The variables of breed, vaccination during pregnancy, disease status in the last 3 months of pregnancy, multiple births (twin), transport, birth type, calf sex, colostrum administration method, Ig rich serum administration and disease status of weaning age were included as categorical variables in the model. In the models, colostrum quality was coded as "low quality = 0" "high quality = 1" and passive transfer failure was also coded as "unsuccessful = 0" "successful = 1". First, the effects of each independent variable on colostrum quality and failure of passive transfer were determined by applying univariate logistic regression analysis. As a result of the univariate analysis, variables with a p value below 0.25 were included in the multivariate model. Variables found insignificant in the multivariate model were removed from the model. Backward elimination method was used in multivariate logistic regression analysis. Odds ratios were used to interpret the final model. All statistical analyses were examined with a minimum margin of 5%. SPSS for Windows 14.01 (License No: 9869264) package program was used. Statistical significance was set at $p < 0.05$.

3. Results

In 69 of 400 serum collected from calves, IgG concentration was measured below 10 mg/mL and FPT prevalence was determined as 17.25%. When evaluated on the basis of farms, the prevalence of FPT starting from the 1st farm to the 9th farm was calculated as 23.64%, 18.29%, 0%, 7.5%, 27.03%, 10%, 21.88%, 18.75%, and 20%, respectively (Table 1). No FPT was observed in calves of farm 3, where 48 calves were included in the study. The highest value was calculated as 27.03% in farm 5. The average serum IgG levels of calves were 14.16 mg/mL, and the average colostrum IgG levels were 90.42 mg/mL.

Various factors and clinical pictures that may affect FPT were evaluated on univariate logistic regression analysis (Table 2).

As a result of the univariate analysis, variables with a p value below 0.25 were included in the multiple model (Table 3).

The final model was built as in the last table (Table 4). Colostrum quality success was found to have a significant effect on FPT (Wald = 17.945; SD = 1; $p < 0.001$). Accordingly, the risk of FPT increases 15.422 times in those with low colostrum quality. The effect of FPT on the frequency of the diseases in calves survived the period until weaning was found to be significant (Wald = 6.655; SD = 1; $p \leq 0.01$). Accordingly, the risk of developing the disease in the period until weaning increases 1.604 times in calves with FPT. It was seen that the effects of other variables examined on FPT have no statistical significance (Table 4).

3.1. Some of the variables affecting FPT

3.1.1. Dystocia

Dystocia were encountered in 41 of the 400 calves. Average IgG concentration of blood serum of calves born to cows with dystocia was 10.82 mg/mL, while average IgG concentration of normal born calves was 14.54 mg/mL. FPT was detected in 48.78% of calves born to cows with dystocia and 13.65% of naturally born calves.

3.1.2. Colostrum quality

A total of 363 colostrum samples were analysed and the average colostrum quality was measured as 90.42 mg/mL. Of these samples 44 (12.12%) had poor quality (<50 mg/mL IgG). FPT was observed in 47.73% of calves consuming poor quality colostrum, on the other hand, FPT was observed in only 11.91% of calves fed with good quality colostrum. Colostrum quality was significantly associated with FPT ($p < 0.001$) (Table 4).

Table 2. Univariate logistic regression analysis results of various variables associated with FPT (1st model).

Effect	Odds ratio	Wald	95% confidence	Interval	p
Dystocia (no vs. yes)	5.464	23.691	2.758	10.826	< 0.001
Colostrum quality success (high vs. low)	6.162	27.207	3.112	12.204	< 0.001
Sex (female calf vs. male calf)	1.177	0.366	0.694	1.999	0.545
Birth weight	1.045	4.897	1.005	1.086	0.027
Initial colostrum administration amount	6.241	14.512	2.433	16.012	< 0.001
Multiple birth (single vs. twin)	1.711	1.546	0.734	3.99	0.214
Initial colostrum administration time	0.632	4.848	0.42	0.951	0.028
Colostrum administration method (bottle vs. catheter)	0.255	9.716	0.108	0.602	0.002
Immune serum application (no vs. yes)	0.596	0.936	0.209	1.7	0.333
Weaning age	0.981	2.433	0.958	1.005	0.119
Weaning weight	1.013	0.212	0.958	1.072	0.645
Getting sick until weaning (no vs. yes)	2.999	15.82	1.746	5.153	< 0.001

Table 3. Multivariate logistic regression analysis results of various variables associated with FPT (2nd model).

Effect	Odds ratio	Wald	95% confidence	Interval	p
Dystocia (no vs. yes)	2.762	1.385	0.509	14.993	0.239
Colostrum quality success (high vs. low)	12.667	12.28	3.062	52.408	< 0.001
Birth weight	1.125	6.08	1.024	1.235	0.014
Initial colostrum administration amount	0.153	1.317	0.006	3.78	0.251
Multiple birth (single vs. twin)	0.061	2.988	0.003	1.455	0.084
Initial colostrum administration time	1.112	0.084	0.542	2.279	0.772
Colostrum administration method (bottle vs. catheter)	0.335	0.874	0.034	3.314	0.35
Weaning age	0.994	0.077	0.953	1.037	0.781
Getting sick until weaning (no vs. yes)	4.073	4.576	1.125	14.75	0.032

3.1.3. Sex

Two hundred and twenty-two of the calves included in the study were female and 178 were male. The average IgG concentration of female calves was 14.08 mg/mL and of male calves was 14.24 mg/mL. The prevalence of FPT in female calves was 18.02% while it was 16.29% in male calves.

3.1.4. Birth weight

Birth weights of 228 calves included in the study. When the calves were divided into 3 groups as birth weights below 30 kg, 30–40 kg and over 40 kg and 25, 160 and 43 calves were allocated into the groups, respectively. In these 3 groups, the average serum IgG concentration, in order of the groups, were 13.32 mg/mL, 14.11 mg/mL and 13.84 mg/mL and the prevalence of FPT was 24%, 16.25% and 18.6%, respectively.

3.1.5. The volume of colostrum or IgG used in the first feeding

Amount of colostrum given in the first feeding was; 46 calves received (12.7%) 2 L and below, 244 calves (67.7%) received 2–2.5 L (2.5 L included), 18 calves (5%) received 2.5–3 L (3 L included) and 52 calves received (14.4%) over 3 L of colostrum. The average serum IgG concentrations obtained from these groups were 11.56, 13.87, 16.36, and 18.36 mg/mL, respectively. When the groups were considered in the same order, FPT prevalence was 30.43%, 17.21%, 11.11%, and 0%, respectively.

The concentration of IgG received by the calf in the first feeding (within the first 4 h) was grouped as; less than 50 g, 50–100 g (including 50 g), 100–150 g (including 100 g), 150–200 g (including 150 g) and 200 g and above. Due to the insufficient number of animals in the first group

Table 4. Results of multivariate logistic regression analysis of various variables associated with FPT (final model).

Effect	Odds ratio	Wald	95% confidence	Interval	p
Colostrum quality success (high vs. low)	15.422	17.945	4.349	54.682	< 0.001
Birth weight	1.1	7.645	1.028	1.177	0.006
Getting sick until weaning (no vs. yes)	1.604	6.655	1.47	16.814	0.01

(3 calves), this group was not taken into consideration in the evaluation. Groups 2, 3, 4, and 5 consisted of 26, 79, 79, and 176 animals, respectively. Starting from group 2, average serum IgG concentrations were 9.22, 10.38, 12.92, and 17.51 mg/mL, respectively and the frequency of FPT in these groups, were 57.69%, 39.24%, 8.86%, and 2.84%, respectively.

3.1.6. Multiple births

Of the calves, 32 were twin and 368 were singleton. The prevalences of FPT in singleton and twin calves were 16.58% and 25%, respectively. While the average serum IgG concentration of twin calves was 12.18 mg/mL, it was measured as 14.33 mg/mL in single-born calves.

3.1.7. Initial colostrum administration

Colostrum was fed to calves within the first 4 h; 98 calves were fed within the first hour of birth, 250 calves in the first 2 h (1–2 h) and 15 calves in the first 4 h (2–4 h). Average IgG concentrations of calves fed within the 1st, 1–2 and 2–4 h were measured as 14.73, 13.84, and 19.58 mg/mL, and FPT prevalence was 7.14%, 19.60%, and 20%, respectively.

3.1.8. Method of colostrum feeding

Of 400 calves 24 received their first colostrum by stomach tube and 376 were bottle-fed. Average serum IgG concentration was 14.29 mg/mL in bottle-fed calves and 11.93 mg/mL in tube fed calves. FPT was 41.67% in tube fed calves and 15.69% in bottle fed calves.

3.1.9. Hyperimmune serum (HS) application

Three hundred and eighty calves were treated with HS and 20 were untreated. The average serum IgG concentrations of HS treated calves was 13.96 mg/mL and was 17.7 mg/mL for HS untreated calves. However, FPT was 25% in HS untreated calves and was 16.84% in HS treated calves.

Among the factors affecting the colostrum quality, those with a p value below 0.25 as a result of univariate analysis were included in multivariate models (Tables 5 and 6).

In the evaluation made in multivariate models, it was observed that the effects of the factors affecting the quality of colostrum were not statistically significant (Table 6).

3.2. Some variables affecting colostrum quality

3.2.1. Age (number of lactations)

Of cows, 69 were in 1st, 163 were in 2nd and 112 were in the 3rd, 15 were in 4th and 4 were in 5th lactation. Average colostrum concentrations starting from the 1st lactation to the 5th lactation were measured as 69.66, 96.85, 92.16, 102.91, and 90.22 mg/mL, respectively. FPT was 23.19% in the 1st lactation, 13.5% in the 2nd lactation, 5.36% in the 3rd lactation, however, the quality of the colostrum of all mothers in the 4th and 5th lactation was above the threshold value.

3.2.2. Dry period

Of cows evaluated, dry period was less than 50 days for 15cows, 50–70 days for 300 cows and more than 70 days for 45 cows. The average colostrum qualities of these 3 groups were determined as 120.28, 87.50 and 101.69 mg/mL, respectively.

3.2.3. Breed

Of dams evaluated, 244 were Holstein, 55 were Swiss Brown and 64 were Simmental. Average colostrum concentration was 89.23 mg/mL for Holsteins, 88.53 mg/mL for Swiss Brown and 96.55 mg/mL for Simmentals.

3.2.4. Vaccine use during dry period

Three hundred and forty-seven of 363 mothers whose colostrum quality analysed were vaccinated during pregnancy, 16 of them were not vaccinated. The average concentration of colostrum were 91.62 mg/mL in vaccinated cows and 64.24 mg/mL in unvaccinated cows.

3.3. Some effects of FPT on calves

3.3.1. Body weight gain until weaning

Daily live weight gain was 0.74 kg in calves with FPT and 0.80 kg in calves with successful passive immune transfer.

3.3.2. Diseases occurrence until weaning

Forty-three 43 out of 69 calves (62.32%) with FPT and 121 of 331 calves (36.56%) with sufficient passive transfer experienced at least one disease until weaning.

4. Discussion

Prevention of neonatal calf morbidity and mortality is mainly dependent on passive transfer of immunity (PTI). The prevalence of FPT is reported to range 19%–41% [4] and it may still be around 25% in farms where management practices are optimum [5]. In this study, the prevalence of FPT was 17.25% which is below than the range reported above. This might be due to the fact that the farms included in this study were exercising good management practices.

Besser et al. and Tyler and Ramsey reported that hypoxia and postnatal respiratory acidosis caused by

Table 5. Various variables that may affect colostrum quality were evaluated by univariate logistic regression analysis (1st model).

Effect	Odds ratio	Wald	95% confidence	Intervals	p
Parity	2.083	15.887	1.452	2.988	< 0.001
Breed	**	2.588	**	***	**
Holstein vs. Swiss Brown	2.641	2.428	0.778	8.962	0.119
Holstein vs. Simmental	0.931	0.031	0.42	2.066	0.861
Vaccine administration during pregnancy (yes vs. no)	0.087	20.818	0.031	2.249	< 0.001
Dry period	0.978	1.431	0.942	1.014	0.232

Table 6. Multivariate logistic regression analysis results of some variables affecting colostrum quality (final model).

Effect	Odds ratio	Wald	95% confidence	Intervals	p
Dams age	5.47	1.773	0.448	66.74	0.183
Dry period	0.893	3.174	0.789	1.011	0.075

dystocia decrease Ig absorption [12,13]. In addition, Tyler and Ramsey emphasized that Ig absorption continued significantly with the second colostrum feeding in hypoxic calves [13]. Drewery et al. emphasized that hypoxia due to labour dystocia does not affect Ig absorption and that increases in FPT in labour dystocia and hypoxia situation may be due to delays in postpartum protocols [14] as was the case in our study where dystocia was associated with low IgG concentration but this was not statistically significant though the prevalence of FPT was high.

Although colostrum IgG concentrations were generally measured close to each other in various studies, very large individual differences were also reported. While average colostrum IgG concentrations are reported in the range of 50–100 mg/mL, this range varies between 1–200 mg/mL when evaluated individually [4,15,16]. Generally, colostrum to be used in feeding is required to contain at least 100 mg/mL IgG or 50 mg/mL IgG in terms of quality [7,17]. Various studies pointed that even in enterprises where herd management practices are carried out consciously, the percentages of colostrum below 50 mg/mL IgG level (poor quality colostrum) vary between 30% and 57.8% [18,19]. Genç found the colostrum IgG concentration as 78.23 mg/mL, Aydogdu and Guzelbekdes found 100.63 mg/mL, Erkılıç found 62.82 mg/mL [20–22]. The rates of poor quality colostrum also greatly varied, Genç found at rate of 7.78%, Kaygısız and Köse found as 20%, Güncü et al., Güncü and Gökçe and Hoyraz et al. stated that no poor quality colostrum was detected using colostrometer [20,23–26]. Çalık reported that all colostrums in their studies were of insufficient quality [27]. In our study, colostral IgG concentration was 90.41 mg/mL and the rate of cows producing poor quality colostrum was 12.12%. These results were in line with above mentioned studies.

Researchers put forward different opinions regarding the effect of sex on colostral passive transfer. Filteau et al. and Perino et al. reported that FPT rates were high in male calves, Genç reported insignificant changes [20,28,29]. Jones et al., on the other hand, explained that the serum IgG levels of male calves were higher than that of female calves [30]. In this study, sex had no effect on average serum IgG concentration and FPT. Our results were similar with that of Genç but differed from three other researchers [20,28–30]. Filteau et al. and Perino et al. attributed the difference in passive transfer success of female and male calves to higher birth weight of males and more difficult births that they might experience [28,29]. When calves born were divided into 3 groups as less than 30 kg, 30–40 kg range and over 40 kg, FPT prevalence was calculated as 24%, 16.25%, and 18.6%, respectively. The difference in prevalence of FPT was not significant but calves with body weight above average had higher FPT percentage than those below the average. The higher FPT was attributed to dystocia due to high birth weight [28,29]. It is thought that the reason for the high prevalence of FPT in the group with a birth weight below the average may be due to the higher percentage of calves with weak and low viability in this group. When the FPT percentages were compared, it is 25% for twin calves and 16.58% for single births which might have resulted from dystocia due to twinning or low birth weight.

Godden reported that 16.8% of growers in the USA used less than 2 L, 43.1% in the 2–4 L, and 40.1% used above 4 L colostrum [9]. In this study, 12.7% of the calves were fed with less than 2 L colostrum, 87.32% of the calves were fed with 2–4 L colostrum. Results were found similar to that of Godden in terms of first feeding with colostrum below 2 L different from other groups [9]. This difference can be interpreted as American farmers are more conscious about passive immune transfer and colostrum issues. The minimum amount of colostrum that should be used for a successful colostral passive transfer, the time of colostrum administration and the quality of the colostrum given cannot be ignored in evaluations due to its direct relationship with the Ig concentration in its content. Calves need 80–150 g of colostral Ig within the first 2–4 h after birth and in proportion to their body weight, if they are to be bottle-fed [5,31]. Godden et al. reported that colostrum replacement feed containing 100 g IgG in calves fed with a bottle within the first 2 h after birth is sufficient for successful colostral passive immune transfer [17]. Chigerva et al. reported that for a successful colostral passive immune transfer, 3 L and more colostrum should be used in the first 4 h and 1 L should be given at the 12th h [32]. On the other hand, Jaster fed the first group 4 L colostrum with an IgG level of 84 mg/mL at the first feeding and the second group 2 L at the 0th and 12th h [6]. After 48 h, IgG concentrations in calf sera were measured as 38.6 mg/mL for group 1 and 45.6 mg/mL for group 2. Jaster reported that feeding with 2 L colostrum instead of 4 L in the first feeding (by adding 2 L more at 12th h) would be more successful [6]. In this study, serum IgG concentrations of calves grouped (1–5) based on amount of colostrum received were 11.55 mg/mL, 13.86 mg/mL, 16.35 mg/mL and 18.36 mg/mL, respectively. According to these results, it is possible to discuss a linear relationship between the amounts of colostrum taken and average serum IgG concentrations. The mean serum IgG concentration of group 1 was significantly lower than the mean serum IgG concentration of group 4 calves. In the present study, the results obtained suggested that the most successful method of feeding was more than 3 L colostrum in the first feeding. Our finding supports the finding of Chigerve et al. but it was different than Jaster, which achieved more successful results in calves fed 2 L colostrum instead of 4 L at the first feeding and an additional 2 L at the 12th h [6,32]. When evaluated in terms of IgG taken with colostrum in the first feeding, serum IgG concentrations starting from the 2nd group to the 5th group are 9.22, 10.39, 12.93, and 17.52 mg/mL, respectively. Godden et al. reported successful PTI for calves received at least 100g IgG within 4 h of birth [17]. In this study group 2 received IgG below 100 g but other groups received above 100g IgG. As in line with Godden et al., calves received IgG above 100 g had serum IgG levels of 10 mg/mL and above [17]. Furthermore as amount of IgG received increased serum IgG levels also increased as reported by Godson et al. and Stott and Fellah [5,31].

After birth, the Ig absorption capacity decreases to 50% at the 6th h and 33% at the 8th h, and comes to a standstill at the 24th h [1]. White reported that the serum IgG level of the group fed only in the first 6 h could exceed the threshold value of 10 mg/mL after birth among the calves who were fed colostrum at 6 h intervals (6, 12, 18 and 24 h), and the calves who could not receive colostrum in the first 6 h had FPT problem [33]. Matte et al. found that the Ig absorption of calves that received their first colostrum at the 6th, 12th, 24th, 36th, and 48th h after birth was 66%, 47%, 12%, 7%, and 6%, respectively [34]. Chigerve et al. reported that there was no significant difference between the 48th h IgG levels of calves fed with 3 L colostrum at different hours within the first 4 h after birth. In this study, all calves were fed within the first 4 h. When the FPT percentages were examined, the results of feeding at different times in the first 4 h did not differ statistically. The results obtained were found to be compatible with the results of the summarized literature.

There are 3 common methods used in colostrum feeding of calves; naturally suckling, bottle feeding and oesophageal tube feeding [9]. Chigerve et al. reported that 4.3% of the producers in the USA preferred oesophageal tube and 59.2% with a bottle [32]. In our study only those who were too weak to suckle bottle or refused to be fed by bottle within 4 h of birth were fed by stomach tubes. Besser et al. compared the cases of FPT that occurred as a result of natural suckling, bottle feeding, and oesophageal tube feeding, and the results obtained were 61%, 19%, and 11%, respectively [35]. In a similar study, Godden et al. reported that FPT rates in calves were 61%, 19%, 64%, and 15%, respectively when the methods used were natural suckling, feeding with a bottle and oesophageal tube using 2 L and 4 L colostrum [36]. The method of colostrum feeding had no significant effect on FPT in our study but stomach tube feeding was associated with increased prevalence of FPT as was reported by Godden et al. [36].

While average serum IgG concentrations of calves given hyperimmune serum in the study were 13.96 mg/mL, this rate was 17.70 mg/mL in calves did not receive hyperimmune. External Ig application was expected to increase average IgG rates but only one farm did not use HS that made comparison difficult and this difference might have also been attributed to other management practices among the farms.

It is known that there is a linear relationship between the maternal serum IgG level and the IgG concentration contained in the produced colostrum. The variables affecting colostrum quality are number of lactations, breed, vaccination applications, diseases survived during pregnancy, dry period and the volume of colostrum produced [5].

All stimulation that the mother's immune system is exposed to in the period up to colostrogenesis affects the colostrum Ig concentration. For this reason, cows exposed to more antigenic stimulation due to their age produce better quality colostrum than primaparous ones that give their first birth [5,9].

Kehoe et al. examined the effects of maternal age on colostrum quality, measured average colostrum IgG concentrations as 83.5 mg/mL in the 1st lactation, 92.9 mg/mL in the 2nd lactation, 107.4 mg/mL in the 3rd lactation and 113.3 mg/mL in the 4th lactation [37]. The researchers concluded that the quality of colostrum increased by age. In a similar study conducted by Pritchett et al., IgG concentrations were 42.8 mg/mL, 50.8 mg/mL, 56.6 mg/mL, and 55.5 mg/mL for the first 2 lactations, 3rd lactation, 4th lactation, 5th and higher lactations, respectively [38]. Saucedo-Quintero et al. found the average colostrum IgG concentrations as 103.43 mg/mL, 87.86 mg/mL, 98.05 mg/mL, and 78.64 mg/mL for lactations 1, 2, 3, 4 and above, respectively [39]. In the study, the highest IgG concentration was found in the first lactation, while colostrum average IgG concentrations were found at the lowest level in cows with 4 or more lactations. Tyler et al. conducted similar studies in Jersey breed cattle and the average colostrum IgG concentrations in cows that they divided into 3 groups as 1st lactation, 2nd lactation and 3 and above lactations were 119 mg/mL, 113 mg/mL and 115 mg/mL, respectively [40]. Similar to the findings of Saucedo-Quintero et al., the best quality colostrum was measured in 1st lactation of cows in this study [39]. In the presented study, average colostrum qualities of cows starting from 1st lactation to 5th lactation were 69.66 mg/mL, 96.85 mg/mL, 92.16 mg/mL, 102.91 mg/mL, and 90.22 mg/mL, respectively. The data obtained was compatible with Kehoe et al. and Pritchett et al.'s with the lowest quality of 1st lactation colostrum and the highest quality of 4th lactation colostrum; was different than Tyler et al. and Saucedo-Quintero et al.'s [37–40].

Morin et al. reported the specific gravity of colostrums as 1.0473, 1.0488, 1.0508 and 1.0524 in their studies in Swiss Brown, Ayrshire, Jersey and Holstein breeds [41]. Wattiaux reported that among 5 different dairy cattle breeds, the lowest quality colostrum belonged to the Holstein breed [42]. On the other hand, Krol et al. reported in their studies on dairy breeds, including Holstein that the average of the lowest quality colostrum belongs to the Simental race [43]. Genç compared the colostrum qualities of Swiss Brown and Holstein cows, they measured the average colostrum quality of Holstein cows as 79.51 mg/mL, and the colostrum quality of Swiss Brown cows as 77.07 mg/mL [20]. Average colostrum quality of colostrums produced according to breeds: 89.23 mg/mL for Holsteins, 88.53 mg/mL for Swiss Brown and 96.55 mg/mL for Simentals. Based on the average colostrum qualities, it is seen that the Simental breed cattle are the most successful, while the Swiss Brown breed is the lowest. Average colostrum IgG concentrations are consistent with Genç's study [20]. As a result of producing high quality colostrum from the Swiss Brown breed of Holstein, it was found compatible with Morin et al. and found different from Wattiaux [41,42]. This study differs from Krol et al.'s results because the highest quality colostrum was detected in simental cows [43]. Chigerwe et al. mainly correlated the effect of breed difference on colostrum quality with the volume of colostrum produced by beef and dairy breeds [44]. Studies have already reported that breed has no effect on colostrum quality as was the case in our study [20, 42–44].

Another variable that increases the colostrum quality is the vaccines administered during pregnancy [8, 45–48]. In contrast, our study determined no effect of dam vaccination on colostrum quality. This was related to unbalanced distribution of cow received vaccine or left unvaccinated which might influenced statistical analyses.

Dry period has effect on the quantity and quality of the colostrum produced [49] and a feasible period is set between 40–90 days [3,5,9,11]. Colostrum quality was not affected by dry period in our study as reported previously [3,5,9,11].

FPT is held accountable for 50% of calf mortality during weaning period. However, Yüceer and Özbeyaz found no affect of FPT on mortality [50]. In our study, FPT had affect on morbidity during weaning period (Wald = 6.655; SD = 1; $p \leq 0.01$). This difference might be attributed to different management practices (feeding, housing condition, population density, sanitation etc.) and seasonal variation which are well known to influence infectious dose of pathogens.

FPT is well known to influence growth performance [51]. Yüceer and Özbeyaz and Virtala et al. reported that FPT was associated with low daily weight gain and Virtala et al. noted 0.048 kg lower daily gain in calves with FPT when compared to those with FPT as was similar to our results where calves with FPT had 0.06 kg lower daily weight gains than those did have FPT but this difference was not significant as reported by Yüceer and Özbeyaz [50,52].

In conclusion, the prevalence of FPT was 17.25% and the percentage of poor quality colostrum was 12.12%. The average serum IgG concentration in calves was 14.16 mg/mL, and the average IgG concentration in colostrum was 90.41 mg/mL. Among the variables examined, only the quality of colostrum was found to be significant. Accordingly, the risk of FPT increases 15.422 times in calves fed poor quality colostrum. When the results of passive immune transfer were evaluated, disease recovery risk increases 1.6 times in calves with FPTuntil weaning. In addition, DLWG decreases by 0.06 kg in calves with FPT. This study is particularly important for professional herd management programs, what FPT is and what its results may cause.

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