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Relationship Between Passive Immunity Levels and Morbidity, Mortality and Growth Rates of Friesian Calves in Egypt

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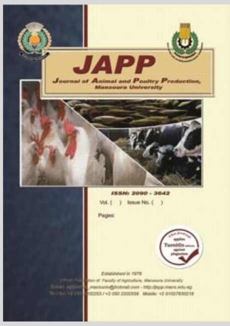

ABSTRACT

The objective of this study was to identify potential biomarkers of future health and performance for Friesian calves by evaluating the serum immunoglobulin G (IgG) levels in newborn calves. Serum samples from 82 calves were collected at 24 to 36 h of age to determine the levels of passive transfer. Body weights (BW) were measured at birth, day 30, and age of weaning (105 days). The occurrence of the disease and the death were recorded. Calves were divided into 3 groups based on serum IgG concentrations as a Failure of Passive Transfer (FPT), Good Protection (GP),and Very Good Protection (VGP).The morbidity rates were 100, 75, and 52.63% for the calves with FPT, GP, and VGP, respectively. In calves with FPT was observed that 35% of these infections were enteric diseases, 25% respiratory diseases, and 40% enteric and respiratory diseases together. While the calves that had GP were observed that 66.67% of these infections were enteric diseases and 8.33% respiratory diseases. In contrast, the calves that had VGP were observed that all of the infections (52.63%) were enteric diseases. The mortality rates were 45.0, 8.33, and 0.0% for the calves with FPT, GP, and VGP, respectively.The calves with FPT had an average daily gain lower (P<0.05) than those who had GP or VGP during the preweaning period. The correlation coefficient between concentrations of serum IgG and the BW at weaning was moderate (r=0.631; P<0.0001).Wherefore,colostrum management should receive appropriate attention to optimize passive transfer status and improve the growth performance of calves.

Keywords: serum IgG, morbidity, mortality, growth, calves

INTRODUCTION

A neonatal period in calves is the most important period affecting its future production capacity. As well as it is the period that the incidence rates of diseases and loss of calves are the highest, therefore it has an important role both in economy and animal management. The main goals of calves rearing are health, growth, and profitability. Passive transfer of immunity for calves through colostrum plays an important role in reaching these goals. During the neonatal period, colostrum management is an important predictor of calf health outcomes and should be evaluated regularly. Calves are born agammaglobulinemic and are dependent on the passive transfer of immunoglobulin G (IgG) from maternal colostrum provided within the first hours of life. Calves that fail to ingest or absorb sufficient colostral IgG, resulting in a serum IgG concentration < 10 g/L at 24 h of life, are considered to have a failure of transfer of passive immunity (Furman-Fratczak *et al.*, 2011; Atkinson *et al.*, 2017; Elsohaby *et al.*, 2019). Newborn calves absorb maternal IgG during the first 24 h after birth; thereafter the absorption capacity is reduced. The recommendation is that the newborns should be feeding large volumes (3 to 4 L) of colostrum within the first 24 h to reach an adequate absorption of IgG (Hang *et al.*, 2017). Feeding high-quality colostrum in adequate amounts has the ability to reduce calf mortality, improve health, promote growth as well as fewer antibiotic treatments and increase milk production and longevity in the dairy cow herd (Godden, 2008; Furman-Fratczak *et al.*, 2011; Hang *et al.*, 2017; Mellado *et al.*, 2017).

An insufficient level of colostral immunity increases the susceptibility of calves to alimentary and respiratory tract infections as well as increases duration of illness and the risk of death in the first weeks of life. Also, diarrhea is the main cause of death of calves up to day 14 of age. Moreover, calves that survive diarrhea before day 14 of life were more susceptible to respiratory tract infections in the ensuing period (Van der Fels-Klerx *et al.*, 2001; Furman-Fratczak *et al.*, 2011; Atkinson *et al.*, 2017). Early detection of health disturbances in calves in cattle farms is difficult because of the large number of individuals (Tourlomoussis *et al.*, 2004; Furman-Fratczak *et al.*, 2011). Some of these response variables can be useful as biomarkers for the performance of calves of the cattle farm because they can provide information about an ongoing disease process, or can predict diseases in the future. Biomarkers can be helpful to group and manage calves in various risk categories. By adopting treatment decisions and protocols on a risk-group or individual basis, it would be possible to improve animal health and reduce both disease incidence and antibiotic use. Also, the use of biomarkers could be an economically feasible approach as some of them do not need invasive techniques and others can be measured in blood already taken during routine checks (Marcato *et al.*, 2018).

Therefore, the objective of this study was to identify potential biomarkers of future health and performance of Friesian calves by evaluate the serum IgG levels in newborn calves and relating these levels to morbidity, mortality, and weight gain during the preweaning period.

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MATERIALS AND METHODS

This study was conducted at El-Qarada Experimental Station, belonged to Animal Production Research Institute, located in the Nile Delta (Kafr El-Sheikh governorate). A total of 82 neonatal Friesian calves were used in this study. The dam parity ranged from 1 to 6 parities. None of the calves suckled from their dam before they were separated after birth. Calves were weighed and housed in individual hutches bedded with rice straw. The dams were milked and the calving date was recorded. The calves were hand-fed fresh colostrum through a nipple bottle (colostrum produced from its mother) within 6 h after birth and first colostrum volume was recorded. All calves were then fed on the transition milk individually for three days and then whole milk at a rate of ten percent of body weight for six weeks at two meals. The milk supply was gradually reduced until it weaning (about 105 days of age). From the beginning of the third week of age, calf starter and berseem hay (high quality) had to be available in front of calves. During the third day of their age, fresh and clean drinking water was available.

Calves were housed in groups in open sheds on the third day of age whereas during feeding times on milk only, they were separated individually. Body weights (BW) were measured at birth, day 30, and age of weaning. The Average Daily Gain (ADG) was calculated by the difference in weight between the start to the end of a period divided by the number of days this period. There were three periods: from birth to 30 days, from day 31 to age of weaning, and from birth to weaning. The calves were daily observed and illness incidence was recorded by the veterinarian, who treated the calves until healing or death. The preweaning morbidity events and causes of death of interest were enteric and respiratory diseases. Enteric diseases were defined as a calf passing abnormal, watery feces (voiding of feces that splattered when hitting the ground), respiratory diseases as a calf showing signs of spontaneous cough and raised the respiratory rate, with or without eye and/or nasal discharge (Mellado *et al.,* 2017). Mortality was defined as the death of calves.

Blood sampling and analysis

Blood samples of each calf were collected from the jugular vein into untreated evacuated tubes at 24 to 36 h of age. All blood samples were centrifuged at 3000 × g for 10 minutes to separate blood serum which was kept frozen at -20°C until later analyzed in the laboratory. Determination of levels of IgG was done by Bovine IgG ELISA kits according to the manufacturer's procedure (Alpha Diagnostic International, Texas, USA). The calves were classified into 3 experimental groups based on serum IgG concentration measured at 24 to 36 h of age as a Failure of Passive Transfer (FPT) = serum IgG <10 g/L, Good Protection (GP) = serum IgG from 10 to 15 g/L, and Very Good Protection (VGP) = serum IgG >15 g/L (Furman-Fratczak *et al.,* 2011; Topal and Batmaz, 2020).

Statistical analysis

The data were statistically analyzed using the General Linear Model (GLM) procedure, SAS (2002). The significant differences among averages were tested using Duncan's Multiple Range Test (Duncan, 1955). Probability values ≤ 5 % were considered significant. Descriptive statistics of morbidity, mortality rates, and causes of disease or death were calculated. The Pearson correlation (r) was used to measure the correlation between serum IgG concentrations measured at 24 to 36 h of age and each of averages daily gain from birth to day 30, day 31 to weaning, and birth up to weaning. Also, the correlations between serum IgG concentrations measured 24 to 36 h of age and both BW at day 30 and weaning day were considered. The correlations were categorized according to Hinkle *et al.* (2003) as negligible (r <0.30), low (r =0.30 to 0.49), moderate (r =0.50 to 0.69), high (r = 0.70 to 0.89), or very high (r ≥0.90).

RESULTS AND DISCUSSION

The birth weights of the calves in the three groups were very similar; there were no significant differences between them, where the overall mean was 34.41±3.81 kg (Table 1). The overall mean concentration of serum IgG at 24 to 36 h of age was 21.02±12.48 g/L (range: 5.36 to 46.13 g/L). The number of calves with IgG concentrations below the cut-off value of 10 g/L was 20 out of 82 calves, which generated a FPT prevalence of 24.39%, their average serum IgG concentration was 7.39±1.28 g/L. While the number of calves that had good protection (GP) was 24 out of 82 calves (29.27%), their average serum IgG concentration was 13.69±1.22 g/L. On the other hand, the number of calves that had very good protection (VGP) was 38 out of 82 calves (46.34%), their average serum IgG concentration was 32.82±7.80 g/L (Table 1).

Table 1. Number of calves and means of BW at birth, serum IgG concentrations, colostrum volume consumed at first feeding, and colostrum consumed/BW of Friesian calves with FPT, GP, and VGP

Item	FPT	GP	VGP	Overall mean
Number of calves	20	24	38	82
BW at birth (kg)	34.30±3.76	34.08±4.37	34.68±3.53	34.41±3.81
Serum IgG concentration (g/L)	$7.39{\pm}1.28^{C}$	$13.69{\pm}1.22^{B}$	$32.82{\pm}7.80^{A}$	21.02±12.48
Colostrum volume consumed at first feeding (L)	$1.38{\pm}0.27^{C}$	$1.75{\pm}0.42^{B}$	$2.23{\pm}0.19^{A}$	1.88±0.45
Colostrum consumed/BW (%)	$4.06{\pm}0.75^{C}$	$5.12{\pm}0.80^{B}$	$6.45{\pm}0.46^{A}$	5.48±1.18

FPT = Failure of Passive Transfer (serum IgG <10 g/L), GP = Good Protection (serum IgG from 10 to 15 g/L), and VGP = Very Good Protection (serum IgG >15 g/L).

A, B, C: Means in the same row with different superscripts are significantly different (*P*<0.05).

The percentage of calves affected by the failure of passive transfer of immunity is consistent with Elsohaby *et al.* (2019) who found that the number of Holstein calves with IgG concentrations below the cut-off value of 10 g/L for FPT positive cases was 36 out of 142 calves, which generated FPT prevalence of 25% and MacFarlane *et al.* (2015) who found this percentage was 26% in the United Kingdom dairy farms. But were lower than the levels as compared with that cited by both Stanek *et al.,* 2019 (34.6% in Czech dairy herds), Vogels *et al.,* 2013 (38% in Australian dairy herds), and Reschke *et al.,* 2017 (43.5% in Swiss dairy herds) and greater than that reported by Beam *et al.,* 2009 (19.2% in the US dairy herds).

The overall mean of colostrum volume consumed at first feeding voluntarily was 1.88±0.45 L, about 5.48±1.18 % of BW (Table 1). It is recommended that at the first colostrum feeding, the calf should intake at least 2 L (about 5% of BW), but that was not achieved in the individuals with FPT, who were consumed 1.38± 0.27 L (range: 1.00 -1.90 L), about 4.06±0.75 % of BW. While this was achieved in some individuals that had GP, who were consumed 1.75±0.42 L (range: 1.30 - 2.7 L), about 5.12±0.80 % of BW. Also, it was achieved in all individuals that had VGP, who were consumed 2.23±0.19 L (range: 2.00 - 2.60 L), about 6.45±0.46 % of BW. Furman-Fratczak *et al.* (2011) obtained similar results: the calves with FPT ingested less amount of first colostrum compared to calves with good protection. They reported that the relatively low amount observed in some calves was associated mostly with poor vitality of calves. Vasseur *et al.* (2009) indicated that the volume of voluntarily ingested colostrum depends on the willingness to suck in calves. Also, Trotz-Williams *et al.* (2008) found that early separation of calves from their dams and feeding an increased volume of colostrum within 6 h of birth is significantly associated with a reduced risk of FPT.

1. The relationship between serum IgG levels and morbidity rate

The level of immunoglobulin G (IgG) may be an interesting indicator for predicting the health of calves in future rearing stages and for evaluating the farm's prophylactic program. Some important correlations between passive immunity levels and the heath of calves were found (Table 2). The overall mean morbidity rate was 70.73 % (58/82) during the preweaning period. The morbidity rate in the calves with FPT at 24 to 36 h of age was the highest (100%; 20/20), while it was 75% (18/24) in the calves that had GP and it was the lowest rate in the calves that had VGP (52.63%; 20/38). These results are in agreement with Marcato *et al.* (2018) who discussed the most important potential biomarkers of health and performance in veal calves. They reported that due to a low functionality of defense immune mechanisms, the animal might have an increase in susceptibility to diseases, and lower IgG of calves contribute to a decreased resilience of calves to diseases. Also, Williams *et al.* (2014) and Mellado *et al.* (2017) indicated that dairy calves with satisfactory passive transfer of immunity have less preweaning morbidity and mortality in addition to lower antibiotic treatments compared to calves with failure of passive transfer, whereas failure of passive transfer of immunity (FPT) is associated with lower productivity, and increased risk of culling later in life. Osaka *et al.* (2014) stated that calves of low serum IgG levels (<10 g/L) are at higher risk for preweaning morbidity and mortality than calves of higher levels of IgG. The mortality rate of calves with serum IgG levels <10 mg/mL was more than twice as high as that of calves with higher IgG levels. Furman-Fratczak *et al.* (2011) found the incidence of disease differed among the groups, from 81.8% in calves group with failure of passive transfer of immunity to 26.7% in calves group that had very good protection. Ali *et al.* (2019) reported that the overall rate of calf morbidity under conditions of the Nile Delta of Egypt was 74.35% during the preweaning period. Also, Hulbert and Moisá (2016) indicated that in USA dairy calves 7 out of 10 calves had been exposed to disease transmission in the preweaning period.

Table 2. Morbidity and mortality rates and cases of enteric and respiratory diseases in Friesian calves with FPT, GP, and VGP

Item	FPT	GP	VGP	Overall mean
Morbidity (%)	100.00% (20/20)	75.00% (18/24)	52.63% (20/38)	70.73% (58/82)
Enteric diseases (%)	35.00% (7/20)	66.67% (16/24)	52.63% (20/38)	52.44% (43/82)
Respiratory diseases (%)	25.00% (5/20)	8.33% (2/24)	0% (0/38)	8.54% (7/82)
Enteric and respiratory diseases (%)	40.00% (8/20)	0% (0/24)	0% (0/38)	9.76% (8/82)
Mortality (%)	45.00% (9/20)	8.33% (2/24)	0% (0/38)	13.41% (11/82)

FPT = Failure of Passive Transfer (serum IgG <10 g/L), GP = Good Protection (serum IgG from 10 to 15 g/L), and VGP = Very Good Protection (serum IgG >15 g/L).

Table 2 shows that the enteric diseases alone occurred in 52.44% (43/82) of calves and respiratory tract infections alone were observed in fewer calves, where it was 8.54% (7/82), while enteric and respiratory diseases together occurred in 9.76% (8/82) of calves during the preweaning period. This is consistent with the results of Furman-Fratczak *et al.* (2011), who found that gastrointestinal or respiratory tract disease occurred in more than half of the calves. Diarrhea occurred in 36.6% of calves and respiratory tract infections were observed less frequently (13.7%). Ali *et al.* (2019) found during the preweaning period that the event rate of enteric diseases was highest (71.18%) than the event rate of respiratory diseases only (12.15%) or enteric and respiratory diseases together (9.50%) or any other causes of diseases (7.17%) under conditions of the Nile Delta of Egypt. Islam *et al.* (2015) found in dairy farms in Bangladesh that the overall event risk of morbidity was 56.17%. The most common disease syndrome was diarrhea with an event risk of 34.82% and pneumonia (6.29%). Hang *et al.* (2017) indicated that 25% of dairy calves (1–60 days age) on smallholdings in Southern Vietnam suffer from diarrhea. A high event of diarrhea is due to poor quality of the colostrum given to the newborn calf, which results in a failure of passive immune transfer (FPT). Also, Żychlińska-Buczek *et al.* (2015) confirmed that 80% of cases of disease during the preweaning period are disorders of diarrhea and respiratory syndrome which were the major cause of business failure and economic losses.

In calves with FPT (IgG <10 g/L), it was observed that 35% (7/20) of these infections were enteric diseases alone, 25% (5/20) respiratory diseases alone, and 40% (8/20) enteric and respiratory diseases together. While the calves that had GP (IgG = 10 - 15 g/L), it was observed that 66.67% (16/24) of these infections were enteric diseases alone and 8.33% (2/24) respiratory diseases alone, there were no infections enteric and respiratory together during the preweaning period. In contrast, the calves that had VGP (IgG >15 g/L) all of their infections 52.63% (20/38) were enteric diseases alone and there were no infections of respiratory alone or enteric and respiratory together during the preweaning period (Table 2).

When studying the extent of the association between serum IgG levels at 24 to 36 h of age and the incidence of enteric and respiratory diseases in general, we noted that there were no significant differences between the means serum IgG levels in healthy calves and calves with enteric diseases alone (27.13±10.64 and 22.10±12.41 g/L, respectively). While calves with respiratory diseases alone or enteric and respiratory diseases together had means of serum IgG levels significantly lower (9.73±3.34 and 6.78±1.34 g/L, respectively) when compared to healthy calves or those with enteric diseases alone (Figure 1).

From these results, it is appears that there is no association between the serum IgG levels and incidence of enteric diseases alone. In contrast, it appears that infection with respiratory diseases or enteric and respiratory together diseases was associated with the passive immune status at 24 to 36 h of age. The results of this study were in agreement with other studies (Moraes *et al.*, 2000; Furman-Fratczak *et al.*, 2011; Marcato *et al.*, 2018) where no association could be found between passive immunity status at 24 to 36 h of age and morbidity attributable to diarrhea. IgG is probable more influential in preventing diarrhea when acting locally in the gastrointestinal tract. For this reason, Moraes *et al.* (2000) proposed that colostrum should be given continuously even after the closing of intestinal permeability to colostral immunoglobulin. In a study by Moraes *et al.* (2000) found that the morbidity rate due to diarrhea was 90.8% in calves from birth until 6 weeks of old. In this study, there were no significant differences between FPT and normal calves. They indicated that the difficulty in finding a relationship between passive immunity and diarrhea is due to the large number and variety of pathogens found in animals and those variables other than the activity of passive transfer determined the appearance of diarrhea in the calves. Topal and Batmaz (2020) indicated that the reason for the high rate of diarrhea in calves had is that it is a multifactorial disease, and the literature supports the idea that the disease may be due not only to passive transfer status but also to environmental and unhygienic environmental conditions in the etiopathogenesis. On the other hand, despite the high rate of diarrhea; however most of the calves did not experience severe diarrhea, the cases were mild. The absence of death despite the high morbidity of diarrhea supports this explanation. While, Marcato *et al.* (2018) reported that levels of immunoglobulins in veal calves upon arrival at the farm, which is reliant on the intake of colostrum, may serve to predict BRD hazard. Calves with IgG <7.5 g/l have a higher probability of death in the first weeks at the farm. However, no relationships were found between neonatal calf diarrhea and Ig levels. Mellado *et al.* (2017) found that colostrum high in immunoglobulin level improved the pneumonia event rate in calves that were fed colostrum with high total coliform counts. The onset of pneumonia depends on complex interactions among various infectious agents, environmental factors, and the immunological status of the calf. Viruses are widely accepted as the first pathogens to intervene, whereas bacteria act as secondary invaders that aggravate the already deteriorated condition of the animal. Contaminated colostrum did not appear to be the source of the lung infection, but the immune system may have stopped functioning at optimal levels, which triggered the outbreaks of pneumonia. They concluded that feeding colostrum with high immunoglobulin level is an essential management method for minimizing the event rate of pneumonia in dairy calves. Furman-Fratczak *et al.* (2011) noticed that after moving the calves to group pens in the calf barn, diarrhea cases occurred in all calves, no cases of respiratory tract infections were detected in the calves group with Ig level >15 g/L at 30–60 h of life.

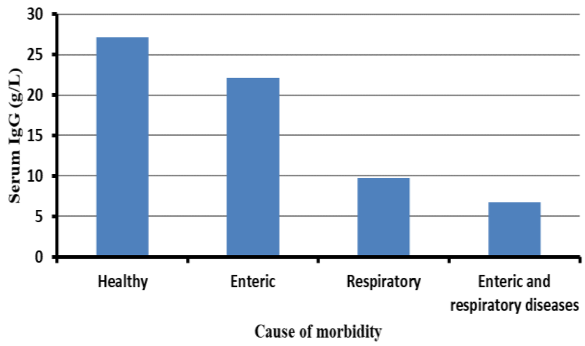

Figure 1. Means of serum IgG at 24 to 36 h of age in healthy calves and calves that incidence of enteric and respiratory diseases during the preweaning period.

2. The relationship between serum IgG levels and mortality rate

Important correlations between passive immunity levels and the mortality rate of calves were found (Table 2). The overall mean mortality rate was 13.41% (11/82) during the preweaning period. The mortality rate in the calves with FPT at 24 to 36 h of age was 45.00% (9/20) and while it was 8.33% (2/24) in the calves that had GP, in contrast, no deaths occurred in the calves that had VGP. All deaths occurred within the first month of life. This result agreed with that reported by Ali *et al.* (2019) who found that the overall rate of calf mortality during the period of preweaning reached 12.16% (210/1727) under the conditions of the Nile Delta in Egypt. The incidence of calf mortality in dairy breeds varies from 2% to 20% under temperate climate (Radostits *et al.*, 2000). Hulbert and Moisá (2016) indicated that the mortality rate among USA calves was 10% during the preweaning period. Patbandha *et al.* (2017) found that the incidence of calf mortality under field conditions in India was16.03%. McCorquodale *et al.* (2013) showed that colostrum management has associated with calf survival; they reported that calves with failure of passive transfer of immunoglobulins are at increased risk of mortality. They found that calves with FPT (serum total protein concentrate <5.0 g/dL) were 2.4 times more likely to die than calves with protected (concentration between 5.0 and 6.0 g/dL). Whereas, a concentration of >7.0 g/dL appeared to provide a protective effect against mortality. Hulbert and Moisá (2016) indicated that calves that have not received colostrum were 74 times more likely to die in the first 3 wk of life. Also, they stated that failure of passive transfer (FPT) of maternal antibodies accounted for almost 40% of the deaths in an experiment with 3,479 calves. Osaka *et al.* (2014) indicated that mortality rate of calves with serum IgG concentration <10 g/L was more than twice as high as that of calves with higher IgG concentrations.

The number of calves that died due to enteric diseases alone was 4 calves, of which 3 calves with FPT and one calf had GP. While the number of calves that died due to respiratory diseases alone was 3 calves of which 2 calves with FPT and one calf had GP. In contrast, the number of calves that died due to enteric and respiratory diseases together was 4 calves all of them with FPT (Figure 2). These results were consistent with those reported by Żychlińska-Buczek *et al.* (2015) who indicated that during the first 90 days of old the main cause of death was diarrhea, the respiratory disorders being the next common cause of loss of calves. Hulbert and Moisá (2016) noted that the mortality rate among calves in the United States was high, with more than half of deaths due to diarrhea. Also, they pointed to that calves that not received colostrum were more likely to die in the first three weeks of age. Also, almost 40% of deaths were due to failure to passively transfer maternal antibodies to calves. Murray *et al.* (2016) reported that intervening with colostrum intake reduced the incidence of death during the preweaning period, ensuring that calves consuming adequate colostrum reduced the risk of failed transfer of passive immunity. Perhaps more colostrum gavage is needed to decrease their risk of death if low vitality calves are identified.

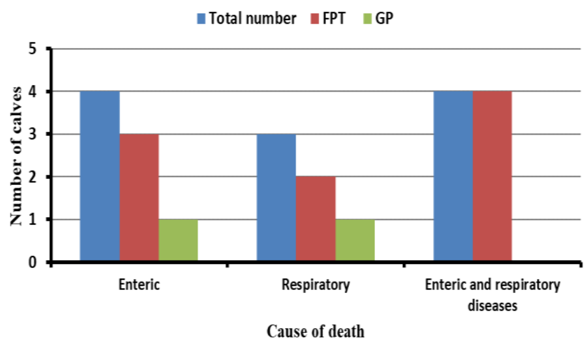

Figure 2. The number of calves that died during the preweaning period and causes of death.

3. The relationship between serum IgG levels and calf growth

Numerous factors are affecting the growth performance of dairy calves, including health status, nutrition, colostrum management practices, and genetic potential. During the neonatal period, colostrum management is an important predictor of calf health outcomes and should be evaluated regularly. The birth weights of the calves in the three groups were very similar; there are no significant differences between them, where the overall mean was 34.41±3.81 kg (Table 3). Serum IgG concentration at 24 to 36 h of age in calves had a significant effect on weight weaning age. Table 3 illustrates the evolution of the means body weight and averages daily gain and its relationship to IgG level in serum in calves during the preweaning period. Indeed, the results indicate that calves that with FPT gained less weight than those who had GP or VGP, in the period from birth to 30 days of age. But this decrease was not significant *(P*>0.05), where the means BW at the end of the first month of life were 44.98, 45.79, and 46.75 kg for the calves with FPT, GP, and VGP, respectively. While during the period from 30 days until weaning, this decrease was significant *(P*<0.05), where the means BW at the weaning age were 80.82, 84.86, and 91.32 kg for the calves with FPT, GP, and VGP, respectively. In contrast, the calves that had VGP had nonsignificantly higher *(P*>0.05) average daily gain than those who had FPT and GV during the period from birth until 30 days, where the ADG during the first 30 days of life were 356, 390, and 402 g in the calves with FPT, GP, and VGP, respectively. While during the period from day 31 of age until weaning the calves that had VGP had a significantly higher *(P*<0.05) average daily gain than those who had FPT and GV, where the ADG were 469, 520, and 594 g in the calves with FPT, GP, and VGP, respectively. This is consistent with Elsohaby *et al.* (2019) who reported that the calves with the adequate transfer of passive immunity have a greater capacity to inactivate pathogenic invasion and mount an earlier response than calves with FPT. Beyond the impact of infectious diseases, calves with adequate colostral immunoglobulin may develop a more efficient metabolic system and grow normally, as opposed to calves with FPT, which has decreased nutrient utilization and reduced feed intake. Elsohaby *et al.* (2019) explained that disease during the preweaning period can affect ADG by suppressing appetite and feed intake. Furthermore, nutrition quantity and quality during the preweaning period are critical for calf growth and significantly affect ADG. In this study, calves fed milk also had access to concentrates and water during the preweaning period, which may have increased ADG. Topal and Batmaz (2020) found that on the day 60, the highest BW increase was detected in the group with serum IgG level > 20 g/L. The difference in BW increase on the day 60 was 6.71 kg in those with serum IgG levels> 20 g/L compared to calves with a serum IgG level of <5 g/L. Murphy *et al.* (2014) indicated that the half-life of colostrum-derived IgG is short (20 to 21 d) but has the greatest impact on health. Atkinson *et al.* (2017) found that calves that have a high serum IgG concentration during the preweaning period tend to show greater BW and ADG than calves with a lower serum IgG concentration. Thus, improving colostrum management practices in dairy farms could result in increased calf serum IgG level and ADG. Mellado *et al.* (2017) reported that daily weight gain tended (*P* = 0.09) to be greater in calves receiving the colostrum with higher immunoglobulin level compared to calves fed colostrum with <85 g Ig/L. The difference in average daily gain for the calves may be due to the combination of higher energy intake from the colostrum rich in immunoglobulin, increased grain intake, and lower fecal scores, indicative of fewer or less severe diarrhea. Both total bacterial counts and total coliform counts in colostrum did not influence the growth traits of calves. Hang *et al.* (2017) reported that the association between serum IgG level after birth and BW extended beyond weaning and they indicated that the health and performance of the calf are of vital importance for its future production ability. The growth rate at an early age has been observed to affect the production ability of adult animals. Moraes *et al.* (2000) reported that calves that had FPT gained less weight than those with normal passive immunity *(P*<0.05). They reported that insufficient amounts of colostrum resulted in increased mortality rates, more severe diarrhea, and lower weight gain in affected calves. However, they indicated that the decrease weight gain in FPT calves could be related to the higher morbidity observed in these calves rather than to the serum Ig concentrations and the weight gain performance in dairy cattle is of utmost importance since it directly affects the age at first calving.

Table 3. Growth performance from birth to weaning of Friesian calves with FPT, GP, and VGP

Item	FPT	GP	VGP	Overall mean
BW at birth (kg)	34.30±3.76	34.08±4.37	34.68±3.53	34.41±3.81
BW at day 30 (kg)	44.98±4.42	45.79±3.51	46.75±2.72	46.04±3.47
ADG from birth to day 30 (g)	356±50	390±74	402±96	387±82
BW at weaning (kg)	80.82±3.82^{C}	84.86±3.97^{B}	91.32±5.63^{A}	87.69±6.37
ADG from day 31 to weaning (g)	469±80^{C}	520±52^{B}	594±74^{A}	552±83
ADG from birth to weaning (g)	434±53^{C}	482±40^{B}	539±51^{A}	505±62

FPT = Failure of Passive Transfer (serum IgG <10 g/L), GP = Good Protection (serum IgG from 10 to 15 g/L), and VGP = Very Good Protection (serum IgG >15 g/L).
A, B, C: Means in the same row with different superscripts are significantly different (*P*<0.05).

Figure 3 shows the relationship between concentrations of serum IgG and ADG in calves during the preweaning period. The correlation coefficient between concentrations of serum IgG and ADG during the period from birth to 30 days of age was negligible (r =0.176; *P* =0.114; Figure 3A). While during the period from day 31 until weaning age was moderate (r =0.542; *P* <0.0001; Figure 3B). Also, during the period from birth to weaning age was moderate (r =0.583; *P* <0.0001; Figure 3C). While Figure 4 shows the relationship between concentrations of serum IgG and BW in calves. The correlation coefficient between concentrations of serum IgG and BW at day 30 of age was negligible (r =0.239; *P* =0.0308; Figure 4A). While between concentrations of serum IgG and BW at weaning was moderate (r =0.631; *P* <0.0001; Figure 4B).

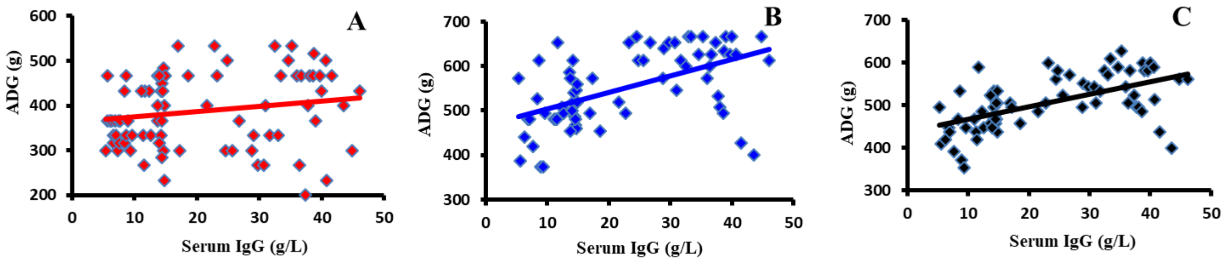

Figure 3. Scatter plots of the relationship between Friesian calves serum IgG concentrations at 24 to 36 h of age and each of (A) ADG from birth until day 30 of age ((r =0.176; *P* =0.114); (B) ADG from day 31 until weaning age (r =0.542; *P* <0.0001); and (C) ADG from birth until weaning age (r =0.583; *P* <0.0001).

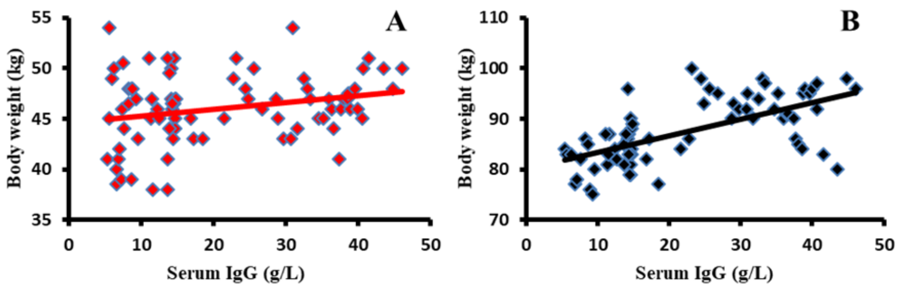

Figure 4. Scatter plots of the relationship between Friesian calves serum IgG concentrations at 24 to 36 h of age and each of (A) BW at day 30 of age (r =0.239; *P* =0.0308) and (B) BW at weaning (r =0.631; *P* <0.0001).

This is consistent with Gökçe *et al.* (2013) who found in a study on lambs that serum IgG level at 24 h after birth was associated with ADG was determined during the period of birth to 28 days (r = 0.151). Each 1 g/L increase in serum IgG at 24 h after birth was associated with a 1.92 g/day increase in ADG and a 69.2 g increase in BW on day 28. While, during the period from day 28 to day 84 of age, serum IgG level at 24 h after birth was significantly *(P*<0.001) associated with body weight gain. Each 1 g/L increase in serum IgG at 24 h after birth was associated with a 2.1 g/day increase in ADG and a 118.5 g increase in weight during the postneonatal period. Also, they explained the relationship between serum IgG level at 24 h after birth and growth performance by two theories, the first that passive transfer of immunity has enhanced efficient metabolic systems and prevent disease occurrence which in turn contributes to better growth performance. Secondly, that lambs receive and absorb not only IgG but also non-immunoglobulin factors present in colostrums which may contribute to growth performance as it is well known that colostrum also contains nutrients, minerals, trace elements, vitamins, enzymes, hormones, growth factors, antibodies, and another immunologically active component such as cells, cytokines and acute-phase proteins which are necessary for normal development. Topal and Batmaz (2020) reported that good Passive transfer status has a positive effect on the increase in body weigth in Holstein calves. Also, they indicated that this increase in BW may be due to the fact that calves with sufficient passive transfer have less disease than calves with failure of passive transfer, and that the epithelial tissue and gastrointestinal development in the intestines are better in calves consuming sufficient immunoglobulin and colostrum compared to calves with FPT. Mastellone *et al.* (2011) reported that there are significant linear associations between serum Ig level 24 h after birth and BW at day 30 of age and between serum Ig level 24 h after birth and ADG from birth to day 30 of age in buffalo calves. They indicated that passive transfer status is a significant source of variation in growth performance during the first month of life when buffalo calves nursed the dam. They suggested that many of these non-immunoglobulin factors in colostrum (ie, cytokines, GH, IGF-1) might have interacted in conjunction with Ig level or acted directly to affect the growth response or to advance the immune and metabolic systems of the buffalo calves allowed to nurse the dam. Wherefore, colostrum management strategy should receive appropriate attention by producers to optimize passive transfer status and improve the growth performance of Friesian calves raised.

CONCLUSIONS

This study reinforced the importance that calves should obtain high immunoglobulin levels through the colostrum. Also, the results obtained indicate that serum IgG concentrations in calves at 24 to 36 h of age vary considerably. These concentrations may be used as prediction indices of morbidity, mortality, and weight gain in calves during the preweaning period. The morbidity and mortality were the lowest in calves with serum IgG concentration exceeding 10 g/L at 24 to 36 h of age. There was a clear relationship between the low serum IgG levels and the occurrence of respiratory diseases. Calves with serum IgG >15 g/L avoided respiratory infections. The correlation coefficients between serum IgG levels at 24 to 36 h of age and averages daily gain of calves during the preweaning period and BW at weaning were moderate (r= 0.583 and 0.631, respectively). Thus, higher levels of serum IgG improve the growth rate of calves.

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العلاقة بين مستويات المناعة السلبية ومعدلات الإصابة بالأمراض والنفوق ونمو عجول الفريزيان في مصر

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الهدف من هذه الدراسة هو تحديد المؤشرات الحيوية المحتملة للصحة والأداء المستقبلي لعجول الفريزيان من خلال تقييم مستويات IgG في سيرم دم العجول حديثي الولادة. تم جمع عينات سيرم من 82 عجل عند عمر من 24 إلي 36 ساعة لتحديد مستويات نقل المناعة السلبية كما تم قياس وزن الجسم عند الميلاد وفي اليوم 30 و105 (الفطام). تم تسجيل حدوث المرض والنفوق. تم تقسيم العجول إلى 3 مجموعات بناءً على تركيزات الجلوبولين المناعي في سيرم الدم وهي مجموعة فشل النقل السلبي (FPT) ، مجموعة الحماية الجيدة (GP) ومجموعة الحماية الجيدة جدًا (VGP). معدلات الإصابة بالأمراض كانت 100 ، 75 و 52.63٪ للعجول FPT ، GP و VGP على التوالي. في العجول التي بها FPT لوحظ أن 35٪ من هذه الإصابات كانت أمراض معوية و 25٪ أمراض تنفسية و 40٪ أمراض معوية وتنفسية معًا. بينما لوحظ أن العجول ذات GP كانت 66.67٪ من هذه الإصابات أمراض معوية و 8.33٪ أمراض تنفسية. بالمقابل لوحظ أن جميع الإصابات (52.63٪) التي حدثت في العجول ذات VGP كانت أمراض معوية. معدلات النفوق كانت 45.00 و 8.33٪ للعجول ذات FPT و GP على التوالي. ولم تحدث أي حالات نفوق في العجول ذات VGP. العجول ذات FPT كان لها متوسط زيادة يومية أقل (P<0.05) من أولئك الذين لديهم GP أو VGP خلال فترة ما قبل الفطام. معامل الارتباط بين تركيزات IgG بالسيرم ووزن الجسم عند الفطام كان معتدلاً (r=0.631 ؛ P<0.0001). لذلك يجب أن تحظى إدارة السرسوب بالإهتمام الكافي من قبل المربيين لتحسين حالة النقل السلبي للمناعة وتحسين أداء نمو العجول.