THE USE OF BOVINE COLOSTRUM AS A SOURCE OF IMMUNOGLOBULIN (Ig) FOR LAMBS

BY

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DECLARATION

I do hereby declare that except for other people's works which have been duly cited and acknowledged, this thesis is the result of my original investigations and has not been presented or published anywhere else either in part or as a whole for another degree.

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DEDICATION

I, dedicate this work to my children Delah, Nunyanuake, Junio and Nuse, and to the memory of my late father, Korbla Akagbo Glover alias "**Tugabizorkponor**".

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ABSTRACT

A study on the use of bovine colostrum as an alternative source of immunoglobulin for lambs was carried out at the University of Ghana's Agricultural Research Centre – Legon. The study involved a total of fifty-six lambs. Thirty-three of them were bottle-fed with frozen bovine colostrum that was thawed whilst the remaining (twenty-three) were allowed to suckle their dams and served as the control. The mean serum immunoglobulin concentrations for the two groups of lambs were measured before the first feeding and thereafter at 6 hrs intervals till 48 hrs postpartum. The growth rates and mortalities for the two groups were also recorded over a period of 42 days. The mean serum immunoglobulin (Ig) concentrations of the normally suckled and the bovine colostrum-fed lambs were 21.01 and 18.26 zst units, respectively. There was no significant ($P>0.05$) difference in Ig levels of the two groups of animals. The peak serum Ig level for the bovine colostrum-fed lambs, however, on the average occurred at 12 hrs postpartum whilst that for the normally suckled lambs occurred at 24 hrs postpartum. The time of peak serum of bovine colostrum-fed lambs occurred earlier in Nungua Blackhead (6 hrs). Sex of lamb had relatively very little effect on immunoglobulin concentration and time of peak Ig in both the normally suckled and bovine colostrum-fed group. The growth pattern of the bovine colostrum-fed lambs at 42 days compared favourably with that of the normally suckled ones. Lambs that died in both groups before the end of the first week did so due to starvation caused by mis-mothering (rejection) by their dams rather than infection. It was therefore concluded that in a developing country like Ghana where knowledge and availability of artificial colostral substitutes/supplements are very limited, bovine

colostrum could be an effective alternative to ovine colostrum in situations where an ewe dies postpartum or cannot lactate normally.

This study also examined the nutritional composition of bovine and ovine colostrum. Pooled colostrum samples were collected from two cattle breeds (Sanga and Friesian-Sanga Crosses) and two breeds of sheep (Nungua Blackhead and Djallonke) in the dry and wet seasons. The samples were analyzed for total solids, protein and minerals to compare the nutritional parameters among the different breeds. The mean value for the protein and total solids content of the bovine colostrum, 12.36 and 16.21%, respectively, were significantly ($P<0.$ and 05) lower than those for the ovine colostrum (14.56 and 22.16% respectively. With respect to bovine colostrum, total solids and protein were higher in the Crosses (19.15 and 13.93% respectively) than in the Sanga breed (16.11 and 12.89%, respectively). With the exception of phosphorus and potassium, the Sanga colostrum was higher in all the major and minor minerals. Similarly colostrum from the Djallonke breed had higher total solids (24.71%) and protein (17.38%) than those from the Nungua Blackhead sheep (21.45 and 13.97 % respectively). Phosphorus and Mg were higher in the Nungua Blackhead, while the Djallonke colostrum was higher in the rest of the minerals.

No significant ($P>0.05$) seasonal variations were observed for the nutrients in bovine colostrum, though the nutrient concentrations were elevated in the dry season compared to those in the wet season. In contrast, ovine colostrum had significantly ($P<0.05$) higher concentrations of nutrients in the dry season. In addition, storage of bovine colostrum for 6 months at a temperature of -4°C had no significant effect on the nutritional quality of the colostrum.

The results of the study showed that even though bovine colostrum could be used to feed lambs, there was early cessation of absorption of bovine immunoglobulins by the gut of lambs. Lambs should therefore be fed as much of the bovine colostrum within the first 12 hrs of life. Ideally, bovine colostrum should be collected in the dry season since colostrum collected in the dry season had higher total solids and proteins than in the rainy season. Bovine colostrum intended to be used for feeding lambs could be stored for as long as 6 months without any deterioration in nutritional quality

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1)	AEA	Apparent Efficiency of Absorption
2)	AOAC	Association of Official Analytical Chemistry
3)	ARC	Agricultural Research Centre
4)	BCL	Bovine Colostrum-Fed Lambs
5)	BW	Birth Weight
6)	DJK	Djallonke Breed of Sheep
7)	DNA	Deoxyribonucleic Acid
8)	EL	Ewe Lambs
9)	FAO	Food and Agriculture Organization
10)	IDF	International Development Foundation
11)	Ig	Immunoglobulin
12)	IGF	Insulin-like Growth factor
13)	IgG	Immunoglobulin G
14)	LSD	Least Significant Difference
15)	MOFA	Ministry of Food and Agriculture
16)	NBH	Nungua Blackhead Sheep
17)	NSL	Normally Suckled Lambs
18)	RL	Ram Lambs
19)	RBC	Red Blood Cells
20)	SC	Secretory Component

21)	SFC	Sanga-Friesian Cross-breeds
22)	SNF	Solids-non-fat
23)	SNG	Sanga Breed of Cattle
24)	SPSS	Statistical Programme for Social Sciences
25)	TGF	Transforming Growth Factor
26)	USA	United States of America
27)	WADG	West African Dwarf Goats
28)	ZST	Zinc Sulphate Turbidity units

CHAPTER ONE

INTRODUCTION

Small ruminants have a significant impact on the nutrition of several Ghanaians living in the rural areas. In most parts of the tropics, sheep and goats provide a consistent and significant supply of animal proteins of high biological value in the form of meat and milk, plus essential minerals and fat-borne vitamins (Devendra, 1981). They also serve as source of ready income for the rural folks in time of need. The short generation interval of small ruminants makes it possible to increase production more rapidly than in cattle; and in the tropics goats have the important advantage over sheep of generally higher fertility level (Blaxter, 1968; Webster and Wilson, 1992). According to Kurt (1988) sheep and goats are preferable to cattle in marginal areas chiefly because of their lower absolute nutrient requirements, better selective grazing ability, broader fodder consumption spectrum and better utilization of less widely available by-products and waste products in all ecological zones.

One distressing factor that is undermining rapid development of the sheep industry is high lamb mortality. Failure to survive the perinatal period is a major form of reproductive inefficiency in farm animals (Osei, 1973; Devendra, 1983; Alexander, 1984). Mortality among the new-born of domesticated animals has important economic implications. Apart from the economic loss resulting from lack of opportunity of the animal to reproduce, Alexander (1984) observed that perinatal deaths also reduce the number of surplus animals available for sale. In the USA for example lamb mortality is believed to range from 10 to 44% (Weiner *et al*, 1973) while in Ghana, Osei (1973) noted that the mortality rate was 20% per annum.

Awumbila and Sumani (1992) reported a mortality rate of 52.7% for lambs in northern Ghana. Most of the lamb mortalities occur within the first week of life (Otesile and Oduye, 1983; Vihan, 1986). Neonatal deaths in lambs are usually associated with lower than average birth weights (Meyer *et al*, 1976), developmental deformities or hypoxia or anoxia during parturition (Brenner *et al*, 1978) and infectious diseases (Radostits and Acres, 1974). In the first two to three weeks of life, diseases causing acute diarrhoea are the major causes of death (Morin *et al*, 1976).

The survival of lambs depends on acquisition of passive maternal immunoglobulin (Ig) transfer to the newborn animals via colostrum within the first 24 hrs postpartum. This is a critically important aspect of neonatal immunity and disease prevention (Gay, 1984). The ruminant placenta is referred to as a "closed system" (Jeffcott, 1975; Pacha, 2000; Hurley, 2002). This means that very few antibodies can cross the placental barrier. Thus, the neonate is born essentially devoid of immunoglobulins in the blood. Hence, the newborn is left with compromised ability to fight pathogens. To acquire initial immunity, the neonate must nurse and absorb the essential immunoglobulins provided in colostrum, or first milk.

In almost all instances, passive immunity in neonates is quantified by the concentration of immunoglobulin G found in the blood stream at 24 to 48 hrs after birth. Indeed, the incidence of neonatal diseases has been found to be positively associated with low serum immunoglobulin (Ig) concentrations in the new born (Nocek *et al*, 1984; Mohammed *et al*, 1991; Besser and Gay, 1994; Perino and Rupp, 1996). In calves, the acquisition of passive immunity has been shown to affect subsequent calf growth even at later stages of life (Wittum and Perino, 1995). The

solution, therefore. is to ensure adequate feeding of good quality colostrum immediately after birth.

As a rich source of immunoglobulins of varying types, colostrum protects against infection in the early stages before the animal's immunity has developed. Tonk (1995) indicated that it takes about 10 to 14 days after exposure to a bacterium before a young animal will become immune to any organism. During this time, background immunity provided from colostrum helps the young to survive while antibody is being produced. Immunoglobulin is not the only colostral factor that may be important in passive immune support in newborn calves. Arthington (2001) reported that cell-mediated immunity might also play a significant role in passive immunity. The significance of cell-mediated immunity is probably most closely associated with maternal lymphocytes (specifically T-lymphocytes), which may be absorbed following colostrum consumption

Availability of alternative sources of high quality colostrum is important for circumventing colostral deficiencies (White, 1993). Alternative Ig sources have been developed commercially and may be used to fortify or replace natural colostrum (Wereme *et al*, 2001). Historically, these commercial products have been derived from lateal secretions; either dried colostrum or concentrated whey sources. Several researchers including Zaremba *et al*, (1993); Francisco and Quigley, (1993); and Mee *et al* (1996) have investigated the effectiveness of these products for both supplementation as well as for full replacement of natural maternal colostrum and have concluded that commercially available products could provide immunoglobulins for passive transfer to newborn calves. There is however, a limited amount of information

available to the Ghanaian farmer regarding the use of alternative sources of colostrum for small ruminants (Osei and others, unpublished). Moreover, commercially available colostral supplements are less efficient in providing immunoglobulin transfer and disease protection to calves, compared to natural colostrum, even if fed equal volume and similar concentration (Garry *et al*, 1996). In kids, Constant and others (1994) and Zadok and associates (2001) reported that commercial replacers were inadequate substitutes for goat colostrum as a source of gammaglobulins. The limited effectiveness of most commercial powders has been broadly attributed to the low concentration of Ig in most commercial powders (Haines *et al*, 1990). Furthermore, studies by Klobasa and associates (1981) have revealed that even though piglets absorbed IgG from bovine colostrum in the same manner as swine IgG, the bovine IgG failed to regulate the level of synthesized immunoglobulins. Holmes and Lunn (1991) obtained similar results with foals, thus suggesting that heterologous Ig was not absorbed as efficiently as Ig from mares.

Being multiparous animals, ewes often produce a larger number of lambs than they are capable of nursing effectively. Hinch and associates (1983) reported that lambs born as triplets or quadruplets have lower chances of survival than twins or singles of the same birth weight. Inadequate intake of colostrum may also occur as a result of the death of a dam or failure of an ewe to lactate normally, poor teat and udder conformation or weak neonates at birth (Alexander, 1984; Radostits *et al*, 1996). Occasionally, there may also be the problem of a dam rejecting her young.

Objectives:

This study therefore sought to:

(i) Evaluate the effect of substituting bovine colostrum as a source of immunoglobulin for lambs;

(ii) Compare the nutritional composition of colostrum from cattle and sheep;

(iii) Compare the nutritional composition of colostrum from two breeds of cattle (the Sanga breed and the Friesian /Sanga crosses) and two breeds of sheep (the Nungua Blackhead and the Djallonke);

(iv) Determine the effect of season on the composition of bovine and ovine colostrum;

(v) Determine the effect of storage on the composition of bovine colostrum.

CHAPTER TWO

LITERATURE REVIEW

2.1 Colostrum

The first food naturally ingested by the newborn infant of any mammalian species is colostrum. It is the first fluid secreted by the mammary glands of all female mammals during late pregnancy and the first few days after parturition. This thick yellowish fluid is rich in immune factors and proteins (Butler, 1971; Payne, 1992). It also contains tissue debris from the alveoli and milk ducts and other residual materials present in the mammary gland before and immediately after parturition (Oser, 1971). It contains essential nutrients, trypsin and protease inhibitors that protect it from destruction in the gastro-intestinal tract (Murray *et al*, 1992). This early secretion is viscous and thus facilitates the passage of meconium (Treacher, 1973). Colostrum performs many functions including laxative function, provision of energy to combat hypothermia (Morris, 1972; Mellor and Murray, 1985) and hypoglycaemia and immunoglobulins, to prevent infection (Treacher, 1973). As a rich source of immunoglobulins of varying types, colostrum protects against infection in the early stages before the animal's immunity has developed. During this time, background immunity provided from colostrum helps the young to survive while antibodies are being produced.

2.2 Components of colostrum

The components of colostrum may be divided into two main groups namely: immune factors and growth factors. These components work together in perfect synergy to maintain health in the neonate. Colostrum has a very high solid content (especially

globulins, minerals and vitamin A), is bright yellow in colour with a strong odour and often a bitter taste (Payne, 1992). Accoding to Foley and others (1972), bovine colostrum contains 28.30% total solids and 21.32% total protein, of which globulins form 15.06% whereas in normal milk the total solids and total proteins form 12.86 and 3.34%, respectively with virtually no globulins.

2.2.1 Immune factors

Immune factors in colostrum have been shown to help the newly born fight off harmful invaders such as viruses, bacteria, yeast and fungus (Radostits *et al*, 1994; Tonks, 1995). The most outstanding property of the immune apparatus of a vertebrate is its capacity to synthesize specific defensive compounds (antibodies) against foreign substances or antigens (Freiburg, 1975). Antibodies are large protein molecules (belonging to a group of glycoproteins called immunoglobulins), which the animal produces to make any invading bacteria or viruses ineffective (Freiburg, 1975; Tonk, 1995). They are synthesised by plasma cells in response to the presence of antigens. Immunoglobulins have been shown to provide a superior defense in both treatment and prevention of viral and, bacterial infections, allergies, fungus and yeast (Selman *et al*, 1971; Logan, 1978; Constance *et al*, 1994). There are energizing elements in colostrum that are anti-inflammatory in nature (Mellor and Murray, 1985). Freiburg (1975) concluded that this is possible because immunoglobulins possess several binding sites that have the capacity to cross-link with the foreign material.

As precipitins, antibodies cause precipitation of macromolecules and as agglutinins they cause foreign cells to aggregate. In addition, they act as antitoxins by neutralizing toxins (Kurt, 1988; Mayr, 1992). Acting as lysins they enable cells to be disintegrated

by the complement factors (system of proteins dissolved in blood which are activated in series and thus cause sequence of biological effects e.g. phagocytosis). Antibodies are produced by an animal following its exposure to an invading foreign agent. Antibody information is then stored and with the help of "memory cells", can be formed more rapidly and in larger quantities when the animal is exposed to the foreign agent again. Besides this humoral antibody effects (i.e. effects resulting from substances dissolved in the blood plasma which are particularly important in defence against pathogenic organisms), there are other reactions brought about by immune cells and by non-specific defensive substances e.g. properdin, interferon etc (Arthington, 2001).

There are five types of immunoglobulins present in colostrum, specifically IgA, IgD, IgG, IgE and IgM (Jones and Hunt, 1983). Bovine colostrum contains 50-150g of Ig/L which consists of 85-90% IgG, 7% IgM, and 5% IgA (Larson *et al*, 1980). The intestine of the neonate is capable of absorbing all classes of immunoglobulins (Besser *et al*, 1985: Radostits *et al*, 1994).

2.2.1.1 Immunoglobulin G (IgG)

There are two distinct subclasses of bovine immunoglobulin Gs namely IgG_1 and IgG_2. The IgG_1 and IgG_2 of cattle have been shown to be antigenically homologous to that of sheep and presumably that of the goat (Butler *et al*, 1971). In goats IgG_1 subclass represents almost the totality of the IgG class (Jones and Hunt, 1983). Bovine IgG_1 of both the serum and colostrum differs from IgG_2. Sasaki *et al* (1977) noted that specific binding sites for IgG_1 increase prior to parturition and a potential new group of receptors appears a week to parturition. Brock *et al* (1977) were of the view that

quantitatively IgG_1 is by far the most important colostral Ig in providing passive immunity to the newborn by intestinal absorption. It is produced as a secondary response to infectious agents. It persists for long periods during which it serves to protect the animal against further infections. IgG is particularly effective in protecting against bacteraemia or septicaemia (Tonks, 1995).

2.2.1.2 Immunoglobulin A (IgA)

Bovine IgA has physico-chemical, distributional and synthetic characteristics similar to those described for human IgA with the exception of those found in the mammary secretion (March and Pahund, 1971; Butler *et al,* 1971). Bovine IgA has homologous properties to that of goat and sheep (Pahund and March, 1970). It constitutes about 5% of colostral Ig (Larson *et al*, 1980).

Immunoglobulin A provides local immunity in the gut, respiratory system and udder (Butler *et al,* 1971; Tonk, 1995). It tends to remain at the site of production and is secreted locally with only low concentrations being found in the serum. The specific immunity produced is helpful to the young animal against enteritis and other gut diseases (Radostits *et al*, 1996). It is often very effective against viruses, since it prevents pathogens from adhering to epithelia and penetrating the underlying tissues (Butler, 1983; Roitt *et al*,1998).

2.2.1.3 Immunoglobulin E (IgE)

Immunoglobulin E is produced in response to parasitic nematodes that undertake blood and tissue migrations (Yamaga *et al*, 1995). Hamilton and associates (1981) reported that IgE is more specific of filariasis in human beings. This was supported by Yamaga

and associates (1995) who concluded that IgE is a better indicator of diethylcarbamine-induced *Dirofilaria immitis* larval death than IgG.

2.2.1.4 Immunoglobulin M (IgM)

Immunoglobulin M (IgM) response is short lived, lasting 24 to 48 hours and is the initial antibody produced in response to enteric pathogens (Waterman, 2002). It has primary protective mechanism against septicaemia, fixes complements; and is a major agglutinating antibody (Kurt, 1988). It constitutes about 7% of colostral Igs (Larson *et al,* 1980).

2.2.2 Other immune factors

In addition to immunoglobulins, colostrum contains specific antibodies to more than 19 specific disease-causing pathogens including Rotavirus (Ebina, 1996), Salmonellae, Candida, Streptococci, Staphylococci and *Escherichia coli* (Tacket *et al,* 1998). Colostrum also contains Proline-rich polypeptide (PRP) which helps in regulating the thymus gland (the body's central command for the immune system) and thus stimulates a weakened immune system as well as balancing an over active immune system as in the case of autoimmune diseases. Other immune factors such as lactoferrin, an iron-binding protein with antiviral, antibacterial and anti-inflammatory properties have been identified in colostrum (Janusz *et al,* 1996).

2.2.3 Growth factors

Several growth-promoting substances known as somatomedins have been identified in colostrum and milk of farm animals (Spron *et al*, 1983; Odle *et al*, 1996). They include insulin-like growth factors (Zuckeller, 1992; Baumrucker and Blum, 1993) and

epithelial growth factors (Odle *et al* 1996). Vega and others (1991), reported that bovine colostrum contains 10 to 500-fold higher levels of insulin-like growth factor one (IGF_1) than mature milk. Due to the high concentrations of growth factors in colostrum, and the presence of specific receptors for these factors within the intestine, Donovan and Odle (1994) suggested that they contribute to early postnatal gastrointestinal development. It has been suggested that they are involved in many biological processes including pre- and postnatal growth, reproduction, lactation and immune function (McGuire *et al*, 1992). In addition, growth factors help regenerate and accelerate the repair of aged or injured muscle, skin, collagen, bone, cartilage and nerve tissues (Spron *et al,* 1983). They also stimulate the body to burn fat for fuel instead of the body's own muscle tissue in times of fasting. Epidermal growth factors in the mare's colostrum are known to promote gastrointestinal growth and inhibit gastric acid secretion thereby enhancing absorption of IgG in the colostrum (Murray *et al*, 1992).

Investigations by Schober and others (1990), indicated that insulin-like growth factor (IGF_1 and IGF_2) receptors have been detected along the entire length of the neonatal intestine. Other workers (Young *et al*, 1990; Baumrucker *et al*, 1994) had similar results thereby confirming the assertion that insulin-like growth factors are one of the most abundant growth factors in colostrum. They influence how the body uses fat, protein and sugar. Somatomedins (growth factors) are one of the groups of substances known to stimulate the synthesis as well as the repair and growth of DNA and RNA (Radostits *et al*, 1994). This makes them an effective anti-aging substance. They have been clinically proven to help increase lean muscle mass and may help regulate blood sugar and cholesterol levels.

In addition to the above, transforming growth factors named A and B have also been found in colostrum. These stimulate the proliferation of cells in connective tissue and assist in the formation of bone and cartilage (Brown and Blackeley, 1983). According to Spron and associates (1983), transforming growth factors (TGF-A and TGF-B) are promising agents in therapeutic bone and wound healing and can help repair tissue. Their presence in colostrum may support the development and growth of the lining of the gut (Opleta-Madsen *et al*, 1991).

2.2.4 Nutrient Elements

Apart from non-nutrient substances (immunoglobulins, enzymes, nucleotides, peptides, polyamides, growth factors, hormones and cytokines), which are needed for specific and non-specific host defense, colostrum contains various nutrients (proteins, essential amino acids, lipids, lactose, vitamins, minerals) which are important for growth and development as well as the over all adaptation of the neonate to new environmental factors after birth (Georgiev, 2005). Colostrum provides high levels of fat and lactose, critical for supporting cold-induced thermogenesis during the early post-natal period (Carstens, 2000). Colostrum is a good source of minerals for neonates. It provides adequate amounts of calcium, phosphorus, magnesium, sodium, potassium and zinc (Salih, *et al*, 1987).

2.2.4.1. Factors affecting nutrient content of colostrum

The composition of colostrum/milk and the factors affecting it have been reviewed comprehensively (Espie and Mullen, 1990; Sakul and Bolan, 1992; Quiles *et al*, 1994). Notable among the factors are species and breed, parity, season of the year, nutrition and diet as well as diurnal variation.

2.2.4.1.1 Species and Breed

The average genetic composition differences between species are considerable (Posati and Orr, 1976) in absolute and relative terms. Ewe milk is generally much higher in solids contents than goat, cows or human milk, but composition categories and contents of individual minerals, fatty acids and amino acids vary in different directions between species, and without relation to higher solids contents (Haenlein, 2002). Within species and within breed, considerable differences in milk composition can be identified for the various breeds through selective breeding. Amino acid substitutions have been identified for the DNA sequences of caprine, ovine and bovine milk protein genes and have been related to the different behaviour of milk proteins (Martin, 1993; Folch *et al*, 1994).

2.2.4.1.2 Parity

Among the factors contributing to differences in the nutrient composition of colostrum is parity. Kume and Tanabe (1993) noted that parity is a major factor altering colostrum composition. They observed that primiparous cows had higher Na concentrations than multiparous cows, but lower protein and K concentrations. It was suggested that the low colostral protein concentration of primiparous cows might be due to low Ig concentration. Although earlier studies (Kume and Tanabe, 1993; Kume *et al*, 1998) showed that the concentration of Ca and P in colostrum at parturition decreased with advancing parity, and their levels of secretion in colostrum were similar in cows at each lactation because of higher milk yield in multiparous cows, recent work (Kume *et al*, 2003) revealed that Ca, P and Mg concentrations in colostrum were not affected by parity. Total solids and proteins however appeared to be positively

correlated with parity. It was suggested that this later finding might be due to improved management and genetic selection.

2.2.4.1.3 Season of the Year

Seasonal variations characterise the concentrations of several constituents in milk and colostrum. In the northern hemisphere, solids-non-fat content of milk is lowest in June/July and highest in fall (Radostits *et al*, 1994). In India, Singh (1979) found that the content of milk fat, SNF, protein, ash and Ca were highest at winter (cold) whilst phosphorus remained constant. In a similar study in Chile, Pinto *et al* (1978) found that the concentrations of Ca and P decreased in winter (cold season) and increased in summer (warm season). Phosphorus again decreased in autumn whilst there was an increase in Na concentration in autumn. These studies thus reveal the fluctuating nature of minerals in milk in relation to season.

2.2.4.1.4 Nutrition and diet

Nutrition has a major effect on milk composition. Regardless of genetics, the composition of daily diet and its amount in relation to production requirements can cause changes in milk composition (Morand-Fehr, 1981; Haenlein, 1995). A low plane of nutrition in late pregnancy results in a marked reduction in the total production of colostrum and in the concentration of nutrients in colostrum during the first 18 hrs after parturition (Mellor and Murray, 1985). High-energy intake is known to increase the SNF percentage but lower the fat percentage (Payne, 1992). Studies have shown that feeding buffers like sodium bicarbonate and magnesium oxide increased milk yield while restoring milk fat content to normal levels (Hadjipanayiotou, 1988). Furthermore, Morand-Fehr (1981) suggested that milk yield, fat content, total protein

and casein contents could be increased by adding a reasonable level of fat to the diet of the cow to increase the energy density. In the same way, the type of protein in the diet and its rumen degradability can affect the milk yield, fat contents and protein level (Andrighetto and Bailoni, 1994). The vitamin content of colostrum is determined by the level and quality of feeding in the last few weeks of pregnancy (Quigley and Bernard, 1995). Vitamin E content of colostrum is usually low unless the dam is provided supplemental dietary vitamin E (Weiss *et al,* 1990). In this respect high quality green forages or hay or silage will raise the vitamin content of colostrum.

2.2.4.1.4 Diurnal variation

The gross composition of milk may also change between morning and evening milkings on the same day (Simos *et al*, 1991). In studies with milking intervals of 8 and 16 hrs the differences were 0.39% fat and 0.05% protein respectively (Merin *et al*, 1988).

2.3 Pathways of transmission of passive immunity

The pathways of transmission of passive immunity involve three main steps:

(a) the secretion of colostrum by the dam;

(b) uptake of immune proteins by the neonate's intestine, and

(c) transfer to the systemic circulation of the neonate (Bush *et al*, 1982; Tonks, 1995; Radostits *et al*, 1995; Pacha, 2000).

2.3.1 The role of the dam

For successful transfer of immunoglobulins from mother to offspring, effective secretion and concentration of immunoglobulin in the mother's colostrum must occur

(Tonk, 1995). The mammary gland has a highly selective ability to transport and concentrate Ig from serum to colostrum (Rouse and Ingram, 1970). In the last few weeks before parturition in ruminants, immune proteins are selectively concentrated from the blood by the mammary gland (Olson *et al*, 1981; Butler, 1983). This begins some weeks before calving or lambing and continues until the time of birth. Olson and associates (1981) reported that transfer of immunoglobulins begins about four weeks before parturition in cattle and reaches a maximum a few days before parturition. In ewes, Cripps and Lacelles (1974) attributed a decrease in the serum immunoglobulin level during the latter part of pregnancy to their transfer to the mammary gland, where antibodies begin to accumulate 12 days prior to lambing and reache high levels 3 days before parturition. Results obtained by Butler (1983) and Jones and Hunt (1983) revealed that immunoglobulin G_1 and G_2 make up the majority of immunoglobulins in cow colostrum and primarily come from the blood (that is they are pre-formed). Hurley (2002) reported that most of the IgA and IgM that are transported into colostrum are synthesized by the plasma cells (B lymphocytes) that reside in the mammary tissue. Transport of the IgGs and the IgA/IgM occurs through the epithelial cells by a process involving small transport vesicles (Hurley, 2003). The receptor for IgA/IgM is called secretory component (SC) and is proteolytically cleaved off the membrane during transport of the IgA (Arthington, 2001). The SC that remains bound to the IgA and the SC-IgA complex is called secretory IgA. However, Larson and others (1980) found a lot of non-bound SC in milk and colostrum, suggesting that the proteolytic cleavage of SC does not require that it be bound to IgA.

Transport of maternal immunoglobulins into colostrum probably occurs in all mammals to varying extents (Brandson *et al*, 1971), but the significance of the

immunoglobulins in colostrum depends on the species. Humans and other primates transport immunoglobulins to the foetus through the placenta via a receptor-mediated, intra-epithelial mechanism similar to that in the mammary gland (Hurley, 2001). Therefore when the infant is born it already has a full complement of immunoglobulins in its blood to protect it from diseases until its own immune system is fully functional. However, in most species immunoglobulins are not transported across the placenta, therefore the colostral immunoglobulins are critically important to neonatal survival (Mohammed *et al*, 1991). This is the case in domestic farm species. In the dairy cow, as much as 2 kilograms of IgG can be secreted into the colostrum during the first five milkings (Larson, 1992; Lee *et al*, 1992; Hurley, 2001). Protein molecules pass out from the vascular lining of the blood vessels and become attached to specific receptors on the surface of the mammary secreting epithelium. They are then transported through the secretory cells into the milk ducts, which transfer the immunoglobulin in the colostrum into the teat sinus and teat of the dam.

In non-ruminants, cells of the gut sensitised to a particular organism migrate to the udder and secrete antibody specific to the particular entity (Tonk, 1995). This ensures that the young receives antibodies specifically to protect against gut diseases. Alterations in quantity and specificity of maternal immunoglobulins may have serious consequences for the health of the young animal.

2.3.2 The role of the Neonate

Most neonates of farm animals need to ingest colostrum from their dam to acquire passive immunity (Logan, 1978; Constant *et al*, 1994). The absorption of colostral proteins takes place by specialised cells of the epithelium of the small intestine in an

active process called pinocytosis (Axelson *et al*, 1989). These cells are non-selective in their uptake so that any large molecules present in the bowel will be absorbed whether they have immunological properties or not (Jeffcott, 1975). Transfer of macromolecules across the intestinal wall represents an important transport mode that facilitates the uptake of a number of protein molecules such as immunoglobulins, growth factors and many antigens, including microorganisms. Sanderson and Walker (1993), noted that this transport is localized in enterocytes and specialized cells called M cells that are involved in the non-receptor passage of intact macromolecules/antigens. The transport of macromolecules is particularly of physiological importance during early postnatal life when it facilitates the absorption of growth factors and immunoglobulin (Ig) G from maternal colostrum and milk. According to Weström and associates (1984), this is crucial for ungulates such as piglets or calves that are born almost agammaglobulinemic but are capable of transferring intact immunoglobulins from colostrum into the circulatory system during the first postnatal days. Nevertheless, other mammals that are born more or less hypoglobulinemic such as the rat, mouse and humans, also receive IgG passively from the maternal milk through the proximal small intestine absorption (Udall *et al*, 1984).

Transport of macromolecules follows two different pathways, namely, specific receptor-mediated transcytosis and non-specific transcytosis (Pacha, 2000). Specific transport macromolecules bind to specific receptors that shuttle them across the intestinal epithelium (Humziker and Kraehenbuhl, 1998). On the other hand, non-selective transport is ensured by vesicular transport of macromolecules that adhere to the surface membrane or are transported in the fluid-phase compartment of the vesicles (Pacha, 2000). The functional ability of the intestinal epithelium to take up

macromolecules seems to be related to the presence of the apical tubular system and large supra-nuclear vacuoles whose distribution and ontogenetic patterns vary dramatically in different species (Menard and Calvert, 1991; Heyman and Desjeux, 1992). The intestine of altricial species like humans, rabbits, dogs and cats contains cells with tubular systems and endocytocis complexes until weaning when the immature vacuolated enterocytes are replaced by mature non-vacuolated cells (Klein, 1989). In ungulates, massive non-selective endocytocis and transport of all intraluminal macromolecules take place during the first two post-natal days within which immunoglobulins compete with other proteins (Besser and Osborn, 1993).

Weström and associates (1982) reported that the effective transport of ingested proteins is facilitated by decreased proteolytic degradation due to the presence of colostral protease inhibitors or anti-trypsin factor. In contrast to ungulates, rat and rabbit milk have a relatively low protease inhibitor capacity (Udall *et al*, 1984), and IgG could escape the degradation by binding to receptors. Macromolecules that bind to the apical membrane in a non-specific manner and non-adherent soluble molecules enter the vesicular system. Gonella and Neutra (1984) as well as Heyman and associates, (1986) suggested that only the adhered macromolecules cross the epithelial layer, whereas the soluble molecules are destroyed. In effect, the neonatal intestine is capable of absorbing macromolecules such as immunoglobulins, growth factors and food antigens from colostrum and milk. The extent of this transfer is related to the importance of passive immunity for the newborns and differs between species. The specific transport of macromolecules is achieved in many cases by binding of luminal factors to specific receptors that shuttle them across the intestinal mucosa without

intracellular hydrolysis (Pacha, 2000). Food proteins cross the epithelium predominantly through specialized M cell (Sanderson and Walker, 1993).

2.3.3 Transfer to systemic circulation

A prerequisite for protective activity is that antibodies reach their site of action without undergoing proteolytic degradation (Mylrea, 1966). In neonates a combination of low gastric acidity, the buffering effect of colostrum and the rapid passage of whey proteins into the duodenum make appreciable peptic digestion unlikely (Besser et al, 1984). The transport of maternal antibodies by the colostrum and their persistence in the blood of the neonate seem to be of major importance (Porter, 1972). Each specialised cell of the intestinal epithelium takes up all the protein it can absorb before discharging them out of the base of the cell into the intercellular space. The protein globules then pass into the local lymphatic vessels and finally reach the systemic circulation via the thoracic duct (Jeffcott, 1973). This complex mechanism of absorption is efficient immediately after birth but declines sharply and by 24 hours it has completely ceased in most species (Bush et al, 1982).

2.3.4 The rate of absorption in different species

The ability of the young to absorb immunoglobulins into their blood lasts only for a period (Boyd, 1972; 1989; Wittum, 1995). As the cells of the gut mature the immunoglobulin is digested or is no longer transported. The sooner colostrum is given to the young the more it can be absorbed. In a study with calves, Logan (1974) showed that the early intake of colostrum was essential if circulating antibody levels were to be adequate. The Ig content of bovine mammary secretions falls rapidly so that after a few days all immunoglobulins and antibody activity would have declined to very low

levels. This is in contrast to findings in the pig in which IgA plays a major role as an *E. coli* antibody throughout lactation (Porter *et al*, 1970), and probably makes a major contribution to local intestinal defence in the young pig. Newborn pigs can obtain adequate serum immunoglobulin levels after one hour of nursing (40 – 60 g of colostrum) and continued nursing does not further increase their serum Ig levels (Coalson and Lecce, 1973). In view of this, Milon *et al* (1983) suggested that the first colostrum received by a newborn pig must be high in Ig levels to ensure that maximal plasma Ig levels are attained, after which the energy content of the colostrum becomes increasingly important. Ducker and Fraser (1976) indicated that unlike calves, colostrum deprivation in lambs for up to 18 hours after birth did not adversely affect antibody levels or growth rate, provided that colostrum intake was adequate once feeding commenced.

2.3.5 Colostrum and mortality

Passive immunity is particularly relevant in the control of infection. An important consideration in materno-foetal-neonate interactions is the influence of maternally derived immunoglobulins and other maternally derived factors on the immunological status of the neonate (Meyer *et al*, 1976). Partial or complete failure of passive transfer of colostral immunoglobulins is a primary cause of disease and mortality in neonatal calves (McGuire *et al*, 1976; Banks and McGuire, 1989; Tizzard, 1992). White and Andrews (1986) reported that calves with inadequate concentrations of IgG were four times as likely to die and twice as likely to succumb to disease as were calves with an adequate concentration of circulating IgG. Penhale and others (1973) examined the individual immunoglobulin classes in calves and found that surviving calves had mean

serum levels of 7.5 mg/ml IgG, 0.8 mg/ml IgM and 0.22 mg/ml IgA; while those dying from septicaemia had levels of 0.8 mg/ml IgG, 0.2 mg/ml IgM and 0.1 mg/ml IgA.

Lambs are born hypo-immuno-competent and with a small store of energy for heat production and metabolism and are dependent on colostrum to supply maternal immunoglobulins and energy (Mellor and Murray, 1985). Findley (1973) and Harker (1974) showed that mortality in lambs was inversely correlated to serum immunoglobulin levels. The most satisfactory way of providing the lamb with immunity against disease is to ensure that it gets a large quantity of good quality ewe colostrum in early life (Osei *et al*, unpublished; Abban, 1999).

The failure to suckle adequate colostrum at birth contributes significantly to the preponderance of early kid deaths, most likely through the mechanism of failure of passive transfer of humoral immunity (Logan, 1978; Radostits *et al*, 1996). Morand-Fehr (1987) reported that 92% of colostrum-deprived kids that died did so within two days of birth. Nandakumar and Rajagopalaraja, (1983) measured serum immunoglobulin (Ig) levels in newborn kids 18 hrs after the ingestion of colostrum. The mean serum Ig concentration of these kids was 735 mg/dl. In the following 2 months, it was realized that the mortality rate of kids with serum Ig levels below the mean was 44% whilst those with serum Ig levels above the mean had a mortality rate of only 3.8%. Thus in most species timely feeding of adequate quantity of good quality colostrum is essential for good health and performance (Besser and Gay, 1984; Starley and Bush, 1885).

2.3.6 Factors affecting Ig absorption

The ability of the neonate to absorb ingested IgG into circulation determines the efficiency of absorption. Quigley (2002) noted that the efficiency of absorption is not an estimate of the total IgG absorbed into the animal but an apparent phenomenon and it is estimated that approximately 50% of absorbed IgG will move out of circulation. Theoretically, the maximum possible apparent efficiency of absorption (AEA) of IgG is about 50% (Quigley, 2002). Different factors have been implicated in the apparent efficiency of absorption. Prominent among these factors are stress, colostral Ig concentration, time of first feeding, breed and sex of animal (Besser and Gay, 1984; Donovan *et al*, 1986).

2.3.6.1 Stress

There is evidence that stressful conditions prior to parturition may affect the Ig absorption capabilities of calves. Among the stress factors are nutrition, dystocia, extreme temperatures and hypoxia or ischemia (Sttot and Reinhard, 1978; Boyd, 1989; Garry, 1993). In a study to examine the effects of nutritional restriction of Angus cows during the last trimester of gestation on neonatal immunity and production, Hough and others (1990) concluded that poor nutrition during prepartum period reduces IgG absorption in calves, even though it did not affect colostrum IgG concentration. Whereas Stott and Reinhard (1978) found no difference between dystocial and eutocial calves so far as Ig absorption was concerned, Donovan and others (1986) reported that dystocia decreases colostral Ig absorption. Investigations by Stott and associates (1979) and Gay (1983) suggested that extreme temperatures reduce Ig absorption in calves. It was suggested that this might be due to the fact that heifers exposed to heat stress in the last 90 days of gestation and in the first week after parturition produce

colostrum with lower IgG, IgA, total protein and fat than non-heat stressed heifers (Donovan *et al*, 1986).

Whilst Rafai *et al* (1981) found that high cortisol concentration decreased IgG absorption in calves, Johnston and Oxender (1979) working with calves and Patt and Eberhart (1976) with piglets, found a positive correlation between increased cortisol concentration and increased IgG absorption. Studies by Hough *et al* (1990) and Whitaker *et al* (1999) indicated that cortisol enhanced immunoglobulin absorption and prevented premature gut closure to absorption in neonatal lambs.

The prevalence of respiratory acidosis immediately postpartum could inhibit the ability of the neonate to adapt to the extra uterine environment (Besser *et al*, 1990; Straun, 1996). Normal birth is generally accompanied by a brief period of hypoxia or ischemia (Szenci, 1985). Garry (1993) noted that there is often an increase in partial pressure of CO_2 (pCO_2) during parturition, which lowers pH, thereby resulting in mild acidosis. Respiratory acidosis may affect apparent efficiency of absorption and the acquisition of passive immunity. Tyler and Ramsey (1991) suggested that hypoxia in calves immediately after birth may delay the absorption of IgG but not affect peak plasma IgG concentration. Guy and associates (1996) reported increased serum IgG_1 concentrations when calves were fed an oral paste of sodium bicarbonate 0.5 hr after the first colostrum feeding.

2.3.6.2. Colostral Ig concentration

The Ig concentration in colostrum used to transfer maternal immunity to the offspring is of primary importance in assuring a desirable passive immunity. In an experiment,

Kluse (1970) observed variations in colostrum yield at first milking after calving and attributed these variations to loss of colostrum from the udder before milking which reduced the chances of getting a high yield of Ig. Petrie *et al* (1984) reported that cows milked intensively, or that experienced excessive colostrum leakage before calving, produce colostrum with reduced Ig content. The concentration of Ig in colostrum also varies according to an animal's disease history, the volume of colostrum produced (Pritchett *et al*, 1991), season of the year (Shearer *et al*, 1992) breed (Roy, 1990; Mowrey, 2001), and parity (Erskine, 1997). Cows tend to produce Ig in response to the pathogens they have been exposed to. Animals exposed to a greater number and varieties of pathogens tend to produce colostrum with greater Ig than those exposed to fewer pathogens. Erskine (1997) noted that concentration of Ig in colostrum is negatively correlated with the volume of colostrum at first milking.

2.3.6.3 Season of the Year and Exposure to Pathogens

Most studies have found no seasonal variations in the percentage of Ig in colostrum (Kluse, 1970; Roy, 1990). This not withstanding, Selman *et al*, (1971) reported that season and geographical location had a significant effect on colostral Ig intake and absorption by different species of animals. Their findings were confirmed by several researchers. In the temperate climate, William *et al* (1975) concluded that monthly serum Ig concentrations were lowest in winter and increased during spring and early summer months. In sub-tropical climates, peak levels have been reported to occur in the winter whiles low levels are associated with the summer months (Stott and Fellah, 1983; Radostits *et al*, 1994). It has been suggested that these variations might be due to decrease in suckling drive in colder months and increase in hotter months. However, Shearer *et al* (1992) intimated that cows calving in August/September produced

colostrum with higher Ig concentrations, hence some of these differences might be due the colostral Ig concentrations.

2.3.6.4. Time of first feeding

The time after birth at which colostrum is fed can also affect the efficiency of Ig absorption (Kruse, 1970). It has been suggested that the decline in AEA is associated with maturation of intestinal epithelial cells (Jochims *et al*, 1994). The decline in apparent efficiency of absorption with increasing age is assumed by Stott and Fellah (1983) to be curvilinear though others (Kruse, 1970) indicate a linear effect. In addition to the above, other factors such as the secretion of digestive enzymes such as trypsin (Thivend *et al*, 1980; Guilloteau *et al*, 1983) and microbial populations in the intestine (James *et al*, 1981) may be involved in reduced AEA. Quigley and others (1995) demonstrated the deleterious effects of proteolytic enzymes on apparent efficiency of absorption by feeding soybean trypsin inhibitor with colostrum to increase the absorption of IgG. Rajala and Castren (1995), on the other hand reported a decline in serum IgG concentration that occurs after birth as another cause of poor absorption.

2.3.6.5 Breed and sex of animal

Roy (1990) compiled data from several studies and concluded that breed differences exist in the efficiency of Ig absorption. Jersey calves fed colostrum or a colostrum replacement product attained 20% higher AEA than Holstein calves fed similar products (Mowrey, 2001). Studies by Edwards and Brown (1982) revealed that in general calves of beef cattle have higher concentrations of Ig than calves of dairy cattle. They pointed out that this is due to the compact udders in beef cows which

facilitate ease of suckling as against pendulous udders in dairy cows. In Ghana, Abban (1999) found that Nungua Blackhead lambs had higher serum Ig levels than Djallonke lambs during the first week of life. In piglets, results obtained by Awotwi *et al* (2000) indicated that there was no significant difference in the Ig levels and pattern of Ig changes between Large White and Ashanti Black piglets. The effect of sex on Ig absorption was studied by Roy (1990) who found that heifer calves had higher serum IgG concentrations than bull calves. On the contrary, Vann *et al*, (1995) reported no effect of calf gender on AEA in *Bos indicus* and *Bos taurus* calves.

2.3.7 Factors affecting the concentration of IgG in the blood

There are many factors that influence the concentration of IgG in the blood of the neonate. These include the mass of IgG consumed, the apparent efficiency of absorption (AEA) and the plasma or serum volume of the animal (Quigley *et al*, 1995).

2.3.7.1 Mass of IgG consumed

The concentration of Ig in colostrum and the volume of colostrum fed are two important factors that can influence the concentration of IgG (Stott and Fellah, 1983). Stott and Fellah (1983) suggested that large amounts of colostrum containing low concentrations of Ig would not be absorbed adequately and this invariably would affect the serum Ig concentration. The concentration of Ig in colostrum, age at first feeding and volume of colostrum fed (within limits) are probably the major factors affecting colostral IgG concentration in the neonate (Quigley, 2002).

2.3.7.2 Blood volume

The amount of IgG in the blood stream is affected by the size of the plasma or serum pool (Quigley, 2002). It is therefore logical that animals with larger blood volume will attain a lower IgG concentration than those with smaller blood volume when fed the same mass of IgG.

2.3.7.3 Method of Feeding

Varied results have been obtained by researchers in terms of the effect of the mode of feeding on Ig concentration. Logan and associates (1981) revealed that calves allowed to nurse their dam normally attain lower serum IgG concentrations and are more susceptible to morbidity and mortality than calves fed by nipple bottle. Two reasons were advanced. First, delay in colostrum consumption by calves allowed to nurse their dams led to maturation of the intestinal epithelium. Secondly, it was believed that calves that nurse their dams consume less colostrum than those fed by nipple bottle thereby lowering IgG intake. In the same way, Besser *et al*, (1991) showed that artificial feeding of colostrum to Holstein calves by oesophageal feeder or nipple bottle could result in a lower prevalence of failure of passive transfer compared with natural feeding. This was attributed to the fact that artificial feeding allows the farmer to regulate the volume of colostrum ingested as well as the time after birth when colostrum is fed.

Contrary to this view Selman *et al* (1970) and Stott *et al* (1979) reported higher absorption for calves allowed to nurse their dam. They postulated that this might be due to the neural effect of the presence of the dam or some labile component in the colostrum. These findings were supported by Lee and others (1983) who proved that

the use of oesophageal feeder to feed large quantities of colostrum resulted in reduced AEA as compared with colostrum administered by nipple bottle. This is because colostrum delivered by oesophageal tube feeder first enters the rumen before moving to the abomasum and finally into the intestine (Leteur-Rowet and Breuink, 1983), causing a delay of about 2 to 4 hrs thereby resulting in the maturation of intestinal epithelial cells.

2.4 Mechanism and time of gut closure

The process of macromolecular absorption is initially high at the first suckling then declines gradually until intestinal closure to uptake of macromolecules has occurred i.e. no more intact macromolecules can be absorbed (Besser and Gay, 1984). This phenomenon is known as "gut closure" and depends on factors such as epithelial maturation or increased intraluminal proteolysis (Telemo *et al*, 1987; Martin *et al*, 1993 and 1997). Intestinal closure is a continual, gradual process that starts immediately after birth and proceeds until there is no longer transport of macromolecules. The time of closure is the time after birth when macromolecules (including immunoglobulins) can no longer pass from the intestinal lumen, through the intestinal cell and into the neonate's vascular system (Hurley, 2003).

Stott *et al* (1979) suggested that contact of the intestinal epithelial cells with ingested colostrum immediately excites pinocytotic activity with the rapid uptake of available macromolecules and other ingested substances into the cells until the finite amount of pinocytotic activity is discharged. This occurs mainly during the first 4 hrs after feeding when the greatest cell-colostrum contact is made and the highest rate of absorption is indicated. With the exhaustion of pinocytotic activity, macromolecules

uptake into the cells is discontinued. The time when transport of macromolecules ceases is species dependent. In newborn pigs, guinea pigs and hamsters, the transport capacity decreases rapidly within the first postnatal days (Lecce, 1973; Lecce and Broughton, 1973), whereas the transfer is terminated approximately 21 days after birth in rats and rabbits (Lecce and Broughton, 1973; Weström *et al*, 1982).

In some species, such as the pig where the intestine undergoes dramatic structural and functional changes during the first 24 hr after birth, the decline in macromolecule absorption may reach 50% of initial values (Puchal and Buddington, 1992; Zhang *et al*, 1997). According to Cruywagen (1990) and Perino *et al* (1993), by 8 hrs post partum, the ability of the calf to effectively absorb immunoglobulins should have been reduced by 50%. Whilst Bush *et al* (1971) reported that gut closure in calves is completed at about 36 hrs after birth. Hurley (2001) reported that closure is completed in the calf by about 24 hr after birth. Piglets when nursed lose their capacity to absorb macromolecules within 12 to 36 hrs of birth (Lecce and Morgan, 1962). Starved piglets on the other hand, retain the ability to absorb macromolecules for 72 – 106 hrs post-partum (Payne and Marsh, 1962; Lecce, 1973), Hurley (2001) observed that in calves. the efficiency of IgG absorption decreases rapidly from 100% at birth to 0% at 24 hrs postpartum. Within the same period the IgG level in colostrum also decreases to about 35%. It was further noted that the concentration of IgG in the serum of calves after colostral diet also increases rapidly until it reaches a peak at 24 hrs and decline thereafter.

The concept that ingested colostrum stimulates pinocytosis in intestinal epithelial cells and supplies sufficient Ig for maximum uptake before pinocytotic cessation, points to

the importance of having sufficient colostral ingestion in the first feeding to contact, excite and initiate all potential absorptive cells linking the walls of the small intestine from proximal to distal end (Stott *et al*, 1979).

2.5 Storage of colostrum

Studies by Quigley, (1998) showed that when colostrum was left at room temperature for any period of time, the growth of bacteria in the colostrum was phenomenal. Within six hours, the number of bacteria in colostrum exceeded 10 million per ml. If colostrum is allowed to sit at room temperatures for extended periods, the risk of infecting young animals with disease-causing pathogens is increased.

High quality colostrum can be stored in a refrigerator for approximately one week without loss of quality (Waterman, 2002) but it can be frozen for up to a year without significant decomposition of Igs or loss of immune activity (Arthington, 2001; Waterman, 2002). According to Quigley (2002), colostrum can be stored frozen for 15 years without serious deterioration of Ig content. Erskine (1997) suggested that colostrum with IgG concentration greater than 50 mg/ml could be stored in the freezer for 6 to 12 months without its effective capacity being affected. The freezer temperature should be between -20°C and - 5°C.

Colostrum quality can be estimated by using a colostrometer (Jardon *et al*, 1999). The colostrometer is a hydrometer device calibrated to associate specific gravity of colostrum with Ig concentration.

The colostrometer classifies colostrum quality (Ig levels) into:

- Poor (red) < 22 mg/ml
- Moderate (yellow) 22 to 50 mg/ml
- Excellent (green) > 50 mg/ml

Since an accurate measure is highly dependent on temperature the colostrometer should be read at room temperature (20 – 25°C). Readings taken below 20°C overestimate the Ig content, while measurements made above 25°C underestimate the colostral Ig concentration (Waterman, 2002).

Lazarro (2002) observed that colostrum collected during the periparturient period contains a total protein of 17.57% and 26.88% total solids. These constituents decline to 10.00% and 20.46% respectively after 6 hrs postpartum. By 24 hrs postpartum, the protein and total solids further decline to a mere 4.52 and 12.77% respectively. Ideally, colostrum for storage should be collected within 4 – 6 hrs after parturition and should be frozen in individual plastic containers in small volumes (Meyer *et al*, 1982). Frozen colostrum should not be thawed rapidly. It should be thawed slowly over warm water or in a microwave to ensure that the Igs are not destroyed. Only the quantity needed should be thawed at a time.

2.6 Colostrum substitutes

The terms "colostrum supplements" and "colostrum replacers" are not well defined in the literature. It is therefore often not clear as to what constitutes a replacer or supplement. Quigley (2002) referred to a colostrum replacer as any preparation that is intended to provide more than 100g of IgG per dose and contains adequate nutrients

required by the calf. In this respect, a "colostrum supplement" is any preparation that contains less than 100g of IgG per dose. Lazzaro (2002) suggested that since supplements are to be fed in conjunction with maternal colostrum to increase IgG concentration, they should provide nutrients such as vitamin E and other fat-soluble vitamins that are inherently variable in maternal colostrum.

Most colostral substitutes currently available are based on available colostrum or whey from non-specific groups of animals. Since much of the constituents of colostrum are derived from blood, the use of colostrum or blood-based products is better than using preparations from milk or milk products such as skim milk or whey (Zaremba *et al*, 1993). The variable colostral substitutes can be categorized into:

2.6.1 Pure colostrum powders

These are dried products containing all the constituents of colostrum. Their quality depends on whether the colostrum is from the first milking only or also includes subsequent milking. If from the first milking, the IgG concentration is about 28.00% (Arthington, 2001).

2.6.2 Whey-based colostrum

This is prepared from the by-product of cheese-making and depending on the method of extraction and concentration, the IgG content may range from 6 – 7 or 25 – 30 g of IgG per dose (Arthington, 2001). Most research indicates that the absorption of IgG from cheese products is poor. Mee *et al* (1996) investigated the use of whey protein

concentrate as a colostrum substitute or supplement for calves and found it to be less effective in conferring passive immunity.

2.6.3 Freeze-dried colostrum

This is obtained from vaccinated cows in selected herds. Supplements derived from freeze-dried colostrum either as a replacement for colostrum or as a supplement to poor quality colostrum have been evaluated by several workers. It contains 25 – 60 g of IgG per dose. Data collected by Garry *et al* (1996) indicated that colostrum supplements are absorbed poorly and calves will achieve only 2 to 3 g of IgG/L when fed these products. This confirmed earlier report by Zaremba *et al* (1993) that IgG absorption from these products is poor.

2.6.4 Bovine serum-derived colostrum

This is prepared from food-grade bovine serum, harvested as a product of the packing industry. The liquid serum is spray-dried into a fine, tan powder containing approximately 20% IgG on powder basis (Arthington, 2001). The powder contains about 45 gm of IgG per dose. Research trials have documented good efficiency of IgG absorption from serum derived colostrum supplements by calves (Quigley *et al*, 1998). Studies by Arthington (2002) have indicated that the apparent efficiency of absorption of IgG from serum derived colostrum supplements is equal to maternal colostrum. Colostrum supplements from serum contain primarily IgG_1 and IgG_2 in approximately equal proportions, as opposed to colostrum-derived supplements, which contain mostly IgG_1. In addition, IgG derived from serum is significantly less expensive in terms of collection, processing and manufacture (Quigley, 2002).

2.7.5 Egg based products

Erhard *et al* (1997) evaluated preparations derived from chicken eggs. These preparations, obtained from hyper-immunization of chickens, contained mainly IgY and were antigen-specific. Their findings, however, indicate that the absorption of these products into circulation appear to be relatively low. Consequently, it was suggested that these preparations might be most useful in post-closure applications.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The experimental sites

The study was carried out at the University of Ghana's Agricultural Research Centre (ARC), Legon about 12 km outside the main campus of the University of Ghana, off the Accra – Aburi main road. The centre lies on longitude 00° 6' W and latitude 05°41' N within the Coastal Savanna zone. The vegetation comprises predominantly of dense thickets and shrubs interspersed with scattered patches of grass. The rainfall pattern is bimodal with the main season occurring between April and June, and the minor season from September to October. The average rainfall is about 600 mm per annum. There is a short dry spell in July-August and a long dry period starting from mid-November to March. The station was established to carry out research in animal breeding, animal nutrition, veterinary medicine, pasture improvement and the development of dairy cattle through cross breeding.

Bovine colostrum, which was used for the experiment, was collected from the Amrahia Dairy Research Station, which is 17 km away from the Legon campus off the Accra-Dodowa road. The station is located a few kilometres away from the foot of the Akwapim Mountains at an altitude of 91.5m above sea level. It lies on longitude 00°8'W and latitude 05°46'N. The area experiences an average of 62 rain days per annum which yields approximately 953 mm of rain per annum. The centre is under the Ministry of Food and Agriculture (MoFA) and funded in collaboration with the Food and Agriculture Organization (FAO).

3.2 Systems of management

3.2.1 Management of cattle at Amrahia

There are two main breeds of cattle at the Amrahia Dairy Centre, namely Sanga and Crosses between the Sanga and Friesian. Except for heifers, all other animals are bred by means of artificial insemination. The Sangas are grazed on natural range as well as developed pastures. This is supplemented in the dry season with rice straw and concentrates. As a preventive measure against Dermatophilosis, the Sanga-Friesian cross-breds are zero-grazed. They are stall fed throughout the year with both fresh or ensiled sorghum and *Panicum*. This is supplemented with Brewer's malt, rice bran, rice straw and copra cake. All animals are fed prior to milking. Regular deworming and routine spraying against ticks are carried out once in a month.

3.2.2 Management of Sheep at ARC

At the Agricultural Research Centre-Legon, the sheep are housed in sheds inside a fenced paddock according to sex and age. Animals are allowed to graze from early morning to late afternoon under the supervision of farm attendants. Feed supplements are occasionally given. A programme of routine monthly drenching is carried out to prevent worm infestation. The animals are dipped once a month in the dry season and twice monthly during the rainy season.

Prior to breeding the ewes are put on a high plane of nutrition for at least two weeks. Their diet during this period comprises of concentrates plus hay and silage, urea ensiled straw, ammoniated straw and urea molasses block in addition to harvested forage. Close to lambing, ewes showing signs of parturition are separated from the rest of the flock and kept under close observation in a paddock near the lambing pen.

3.3 Experimental Units

Close to parturition, dams exhibiting signs of parturition were separated from the rest of the flock and kept under continuous observation in a small paddock or pen. The newly born lambs were selected at random into two experimental unit, weighed and ear-tagged after physical examination.

3.4 Method of colostrum collection

Mammary secretions were collected from several multiparous cows by hand-stripping of the mammary glands from zero through 8hrs after parturition when there was free flow of colostrum. Samples were bulked and mixed thoroughly to provide a single source of natural bovine colostrum. The pool of colostrum was then divided into aliquots and placed in plastic freezer bags and stored frozen at – 4°C for later use.

3.5 Determination of immunoglobulin concentration

The serum Ig concentration of lambs was determined indirectly using a pocket refractometer (Fig.1) (Belhinghan and Stanley Ltd. Model L10) as described by Reid and Clifford (1974). The refractometer works on the principle that the refractive index of a solution is determined by its concentration (McBeath *et al*, 1971). The method is a quantitative test which gives a measure of total protein and thus an indirect measure of the amount of immunoglobulin. According to O'Brien and Sherman (1993), there is a reliable correlation between the refractometer reading and the total serum Ig concentration as measured by single radial immunodiffusion as well as between the reading and the zinc sulphate test value which is a good estimation of serum Ig level. The Ig level is measured in zinc sulphate turbidity (zst) units on a scale ranging from zero to fifty.

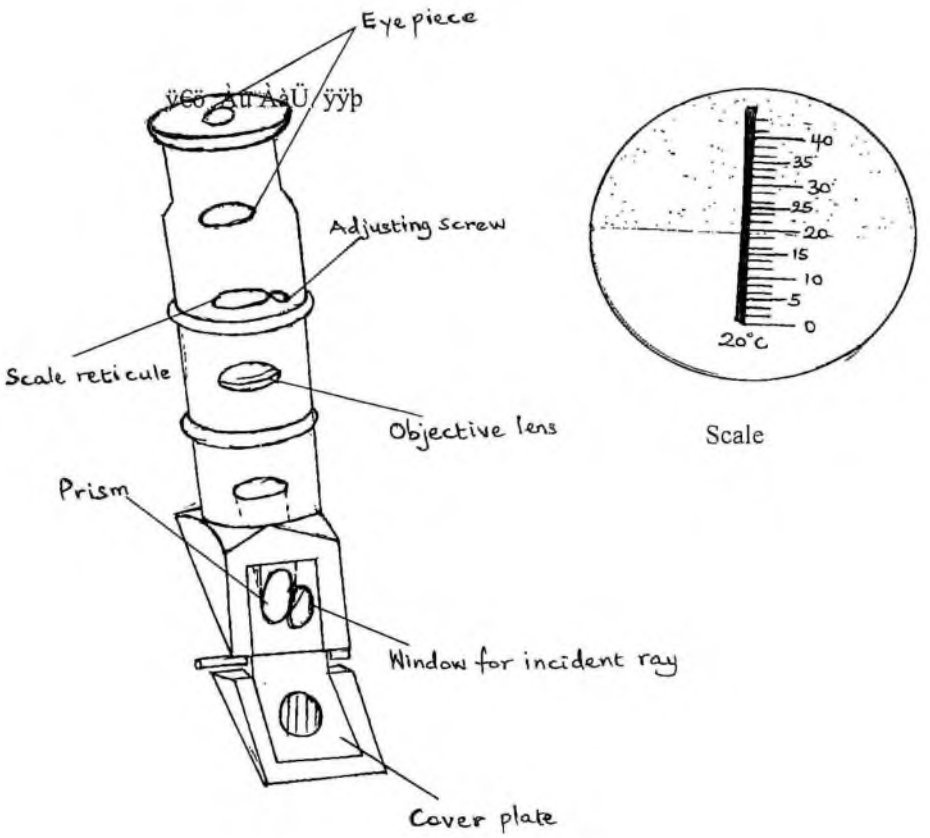


Figure 1: Components of a Pocket Refractometer

Prior to serum protein measurement, the scale was adjusted by placing a few drops of distilled water on the face of the prism and focusing the scale to ensure that the boundary line falls on the wet line. After this a drop of the serum was placed on the glass plate and covered with the cover plate. The refractometer was then held with the cover plate directed towards the bright sky and the Ig reading noted on the scale through the eye piece.

3.6 Experimental protocol

Experiment I: Determination of serum Ig concentration in neonates normally suckled or fed with bovine colostrum

Data was collected from fifty-six lambs; twenty-three of which were allowed to suckle their dams (group one) whilst the remaining thirty-three were bottle-fed with thawed-frozen bovine colostrum by means of nipple feeding bottle (group two). Group one lambs were made up of fifteen Djallonke (DJK) lambs and eight Nungua Blackhead (NBH) lambs whilst group two lambs comprised of twenty-three DJK and ten NBH lambs. There were twelve males and eleven females in group one and seventeen males and sixteen females in group two. Immediately after lambing each lamb was weighed and the birth weight recorded before being put into an experimental group. The first feeding for group two lambs was done within the first 1 hour after birth, and the subsequent meals were fed at 6 hours intervals till 48 hrs. At each feeding, lambs were allowed to suckle as much colostrum as they could. Each feeding bottle contained about 100 mls of colostrum and on the average each lamb took in about 70 mls. After 48 hrs the lambs were allowed to suckle their dams.

To prevent the problem of rejection of bottle-fed lambs by dams there was no physical separation of dams and neonates. The bovine colostrum-fed lambs were kept with their dams in the same pen. However, to prevent the lambs from suckling, they were placed in open top cages. Even though the dams had access to their lambs through the top of the cage, the lambs could not suck them. At the time of administration of colostrum to animals in group two, the frozen colostrum was thawed by placing it in warm water at

38°C. To minimize excessive heating, the thawed colostrum was periodically poured off. Only the quantity needed at a time was thawed and used.

Blood samples were collected from both groups via the jugular vein soon after birth and prior to initial feeding of colostrums and allowed to clot. Thereafter samples were collected at six hours intervals till 48 hrs after birth. The blood was collected using a 5 ml syringe and needle by means of jugular venipuncture. Each sample was centrifuged at 2000 revolutions per minute (rpm) for 10 minutes to obtain the serum.

Mortality records were kept for all lambs up to weaning. For each lamb that died autopsy was carried out to ascertain the cause of death. The growth of the lambs was monitored through regular weighing. The weighings were carried out daily for the first week and thereafter on days 14, 21 and 42.

Experiment II: Determination of the effect of species, breed and season on nutritional composition of colostrum

Samples of colostrum were collected from two breeds of cattle [the Sanga (SNG) and the Sanga-Friesian crosses (SFC)] and two breeds of sheep [the Nungua Blackhead (NBH) and the Djallonke (DJK)] during the rainy season (May-July / Sept-Oct) and during the dry season (mid Nov-February) of 2004. Each sample was analyzed for protein, total solids and minerals immediately after collection to determine its nutritional composition. Some wet season samples from the Sanga were stored in the deep freezer at a temperature of -4°C for a period of six months for later analysis to determine the effect of storage on the composition.

(a) Determination of total solids in colostrum

Three grammes (3g) of colostrum samples were weighed into flat-bottomed dishes and heated on a water bath for about 30 minutes. The samples were then transferred into pan oven and heated at 100°C for 3 hrs. Each sample was then weighed after cooling in a desiccator. The residues (differential weight) were then expressed as percentages of the original samples.

(b) Determination of Protein in Colostrum (Kjeldahl Method)

The protein was determined using the Kjeldahl sulphuric acid method for the determination of protein (AOAC, 1995). About 5 g of each sample were weighed into Kjeldahl digestion flasks. Fifteen grams of K_2SO_4 + 0.8 g of $CuSO_4$.$5H_2O$ and 25 ml H_2SO_4 were added to each sample in the flask. The samples were then transferred onto an automatic digestion system (Tecator's Digestion System, Model 2020).

The digestion lasted for about 2 hrs after which the rack was removed to allow the digesta to cool. The digesta was then connected to an automatic distillation apparatus (KJEJTEC Distillation System Model No. 1026) and heated until all NH_3 was distilled in a flat bottom flask.

The receiver was washed thoroughly and the excess acid titrated with NaOH solution. A blank was also prepared at the same time. The following calculations were made:

Percentage protein was calculated as %N * 6.38.

Percentage N = (T-B) * 14.007 * N * 100 / Weight of sample; where:

T = sample titre value; B = blank titration and N = normality of acid.

(c) Determination of minerals in colostrum (Moist Combustion Incineration Method)

The moist combustion incineration method was used. Ten milliliter of conc. HNO_3 was added to 5 g of the colostrum samples in 100 ml micro-kjeldahl digestion flasks. Blanks were also prepared at the same time. The samples were boiled to reduce their volume to about 50 ml. They were then allowed to cool after which 10 ml of conc. H_2SO_4 and 5 ml of HNO_3 were added and heated until white fumes appeared. They were allowed to cool and 10 ml of ammonium oxalate solution added. Heating was continued until copious white fumes were produced. Fifteen ml of deionized water were carefully poured down the side of the flask allowing fumes to escape through the fume chamber (hood). The digesta was then filtered through N°1 whatman filter paper into a 50 ml volumetric flask. The kjeldahl flask was rinsed (three times) into a filter funnel with small volumes of deionized water (1-2 ml). The residue was rinsed on filter paper (3x) and the funnels were also rinsed after removing the filter paper. The digest was then brought to volume (50 ml) and transfered to 60 ml holding bottles after mixing thoroughly.

The concentrations of Ca, Mg, Fe, Mn and Zn were established by atomic absorption spectrophotometry by blowing a solution of the sample into the flame of an air-acetylene mixture, with increased sensitivity by means of additional extension of the slotted tube atom trap. Potassium and sodium were determined using the flame photometry method by means of a flame photometer.

3.7 Statistical analysis

The Ig values of serum from the two experimental groups were presented as means and plotted against time. Comparisons between groups of lambs were performed for body

weight (BW) at birth, serum Ig concentrations, weaning weight and mortality. Comparisons were also made between breed, sex and birth weight in relation to Ig levels and mortality. Lambs were grouped into three birth weight categories (1.00-1.50, 1.51-2.00 and those above 2.00 kg).

Data on protein and total solid content of colostrum were presented in percentages whilst the mineral composition was in mg/L. The data was subjected to analysis of variance (ANOVA) to test the effect of species, breed and season on the composition of colostrum. When significant differences were found, means were separated using LSD (Steele and Torrie, 1980). Simple linear regression and correlation among the nutrients were carried out using the computer-based programme, SPSS version 10. All other statistical analyses were made using a computer based statistical programme (Genstat). Comparisons were made at 5% level of significance or otherwise indicated.

CHAPTER FOUR

RESULTS

4.1 Mean and peak Serum Ig concentrations in lambs

The mean serum Ig concentration of normally suckled lambs and lambs artificially fed with bovine colostrum are shown in Table 1. The two groups of lambs had insignificant levels of serum Ig concentration before their first feeding. The mean serum Ig concentration for the bovine colostrum-fed and the normally suckled lambs were 18.26 and 21.01 zst units respectively. Analysis of variance revealed no significant differences ($P>0.05$) in serum Ig concentration between lambs belonging to the two colostral treatment groups (Table 1).Values for post-colostral Ig absorption against time ranged from 12.8 to 28.5 zst units for the normally suckled group and from 12.2 to 24.5 zst units for the bovine colostrum-fed group. The peak serum Ig levels for the normally suckled lambs on the average occurred at 24 hrs while that for the bovine colostrum-fed lambs occurred at 12 hrs (Fig. 2). The peak serum Ig concentration for the normally suckled lambs (28.5 zst) was significantly higher ($P<0.05$) than that of the bovine colostrum-fed lambs (24.5 zst).

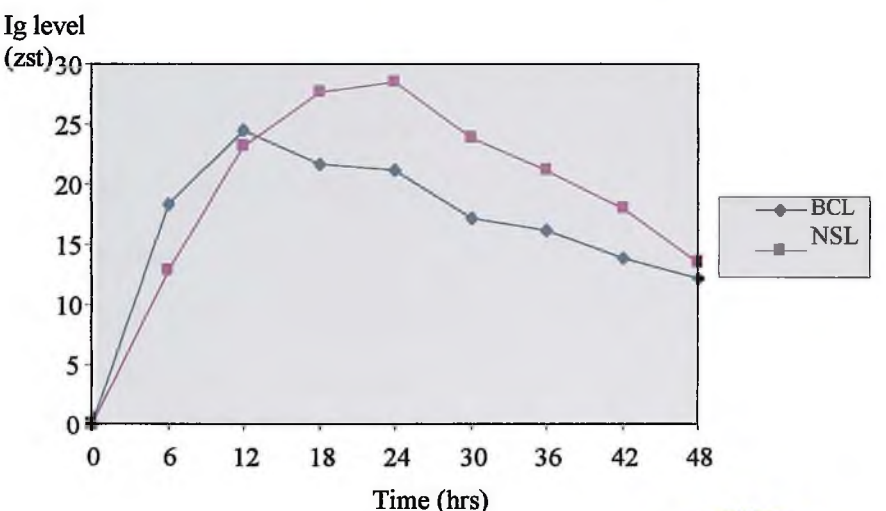
Table 1: Mean and peak Immunoglobulin (Ig) concentrations in normally suckled and bovine colostrum-fed lambs during the first 48 hrs of life.

Group	No	Mean Serum Ig (zst)	Peak Serum Ig (zst)
NSL	23	21.01 ± 1.04[a]	28.5 ± 1.59[a]
BCL	33	18.26 ± 0.95[a]	24.5 ± 1.33[b]

NSL - Normally suckled lambs
BCL – Bovine colostrum-fed lambs

* Means in columns with different superscripts are significantly different.

Figure 2: Serum Immunoglobulin concentration in normally suckled and bovine colostrums-fed lambs.



NSL - Normally suckled lambs (n=23)
BCL – Bovine Colostrum-Fed (n=33)

4.2 The effects of breed, sex and birth weight on serum Ig concentration in normally suckled and bovine colostrum-fed lambs.

Breed of lamb had no effect on serum Ig concentrations in both the normally suckled and the bovine colostrum-fed lambs during the first 48 hrs (Table 2).

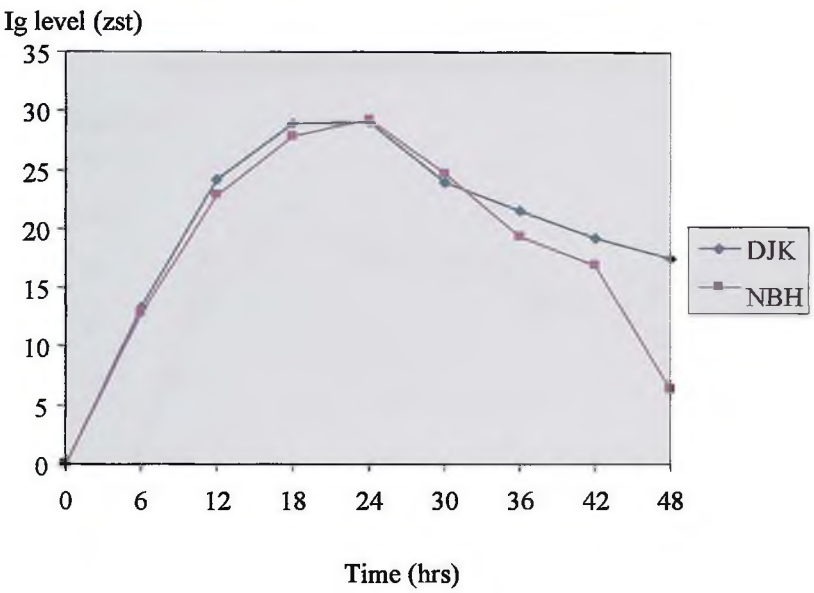
Table 2: Effect of breed, sex and birth weight on serum immunoglobulin concentration in normally suckled and bovine colostrum-fed lambs

Parameter	Bovine colostrum-fed lambs		Ovine colostrum-fed lambs	
	No	Mean ± SE (zst)	No	Mean ±SE (zst)
Breed :				
DJK	23	18.10±3.78 [a]	15	21.69±5.60 [a]
NBH	10	18.63±5.89 [a]	8	19.75±6.98 [a]
Sex :				
Male	17	17.57±1.34 [a]	12	20.30±1.41 [a]
Female	16	19.00±1.37 [a]	11	21.79±1.58 [a]
Birth weight (kg):				
1.00 – 1.50	7	19.44± 0.69 [a]	5	19.93± 1.61 [a]
1.51 – 2.00	19	21.15±1.62 [a]	11	18.14± 1.35 [ab]
> 2.00	7	21.93±2.16 [a]	7	16.75± 2.16 [b]

Means with same superscripts are not significantly different (P>0.05), within a factor.

In the normally suckled lambs, both the Nungua Blackhead (NBH) and the Djallonke (DJK) had their peak serum Ig level at 24 hrs postpartum. Thereafter the decline in Ig level was much more rapid in the Nungua Blackhead than in the Djallonke (Fig. 3). Though the Nungua Blackhead lambs in this group had slightly higher peak than their Djallonke counterparts, the difference was not significant (P>0.05).

Figure 3: Serum immunoglobulin concentration of normally suckled Djallonke and Nungua Blackhead lambs



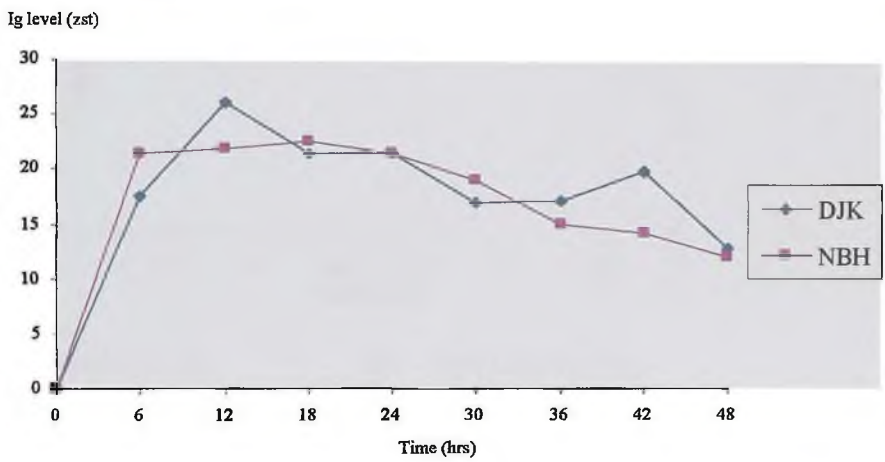
DJK – Djallonke Lambs (n = 15)

NBH – Nungua Blackhead Lambs (n = 8)

In contrast, the Djallonke lambs in the bovine colostrum treatment group had a significantly higher ($P<0.05$) peak serum Ig level than their Nungua Blackhead counterparts in the group (Fig. 4). However, the Ig levels of the Nungua Blackhead lambs peaked earlier (6 hrs) than that of the Djallonke lambs (12 hrs) in this group.

Figure 4

Serum Immunoglobulin concentration in Djallonke and Nungua Blackhead lambs bottle-fed with bovine colostrum

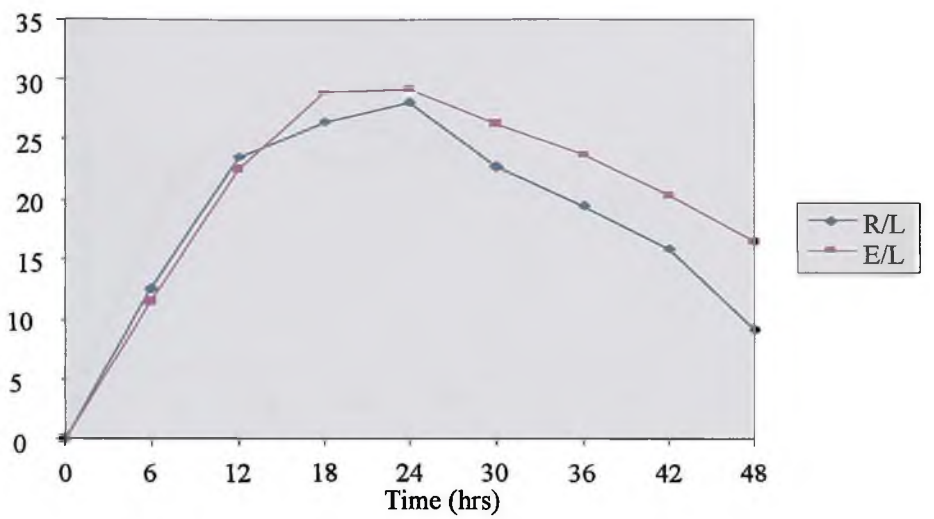


DJK – Djallonke (n = 23)
NBH – Nungua Blackhead (n = 10)

In terms of sex, female lambs had higher peak Ig levels than their male counterparts in both the normally suckled and the bovine colostrum-fed groups. These were however, not statistically significant ($P>0.05$) (Table 2). The Ig level of ewe lambs in the normally suckled group peaked at 18 hrs and remained stable until 24 hrs before

declining slowly. Ram lambs in this group had their Ig peak at 24 hrs and decilined rapidly thereafter (Fig. 5).

Figure 5: Serum immunoglobulin concentration of normally suckled male and female lambs



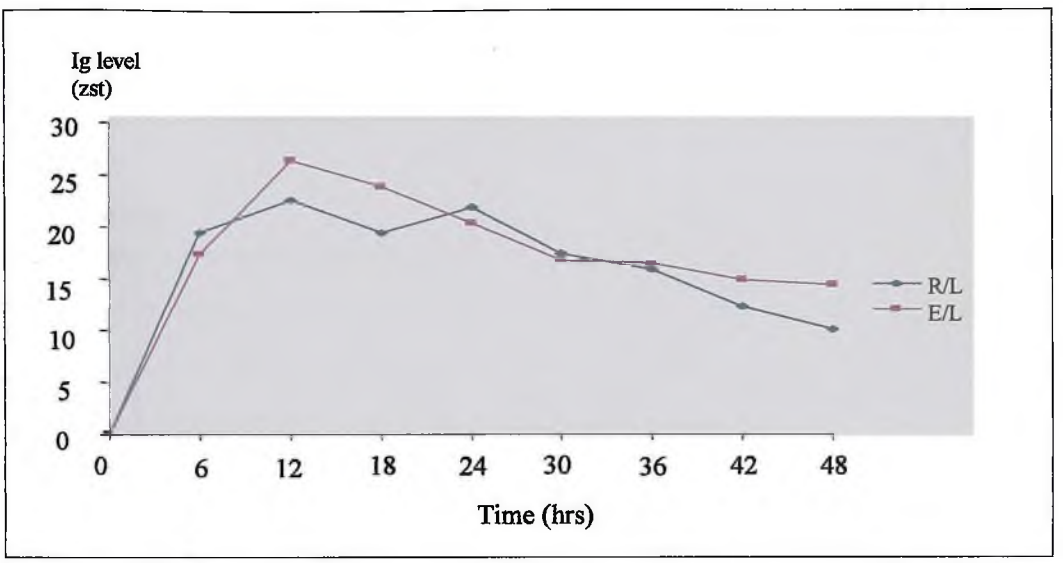
R/L – Ram Lamb (n =12) E/L – Ewe Lamb (n =11)

On the other hand the female lambs in the bovine colostrum-fed lambs had their peak Ig levels at 12 hrs (Fig. 6) whilst that of the ram lambs fluctuated between 12 and 24 hrs.

The results indicate that in the normally suckled lambs birth weight had a significant effect on serum immunoglobulin concentration with lambs in the low weight group (1.00-1.50 kg) having significantly higher ($P<0.05$) Ig concentrations than those in the

higher weight group (2.00 kg and above). In contrast, birth weight had no effect on Ig absorption in the bovine colostrum-fed lambs.

Figure 6: Serum immunoglobulin concentration in male and female lambs fed with bovine colostrum



R/L –Ram Lambs (n = 17) E/L – Ewe Lambs (n = 16)

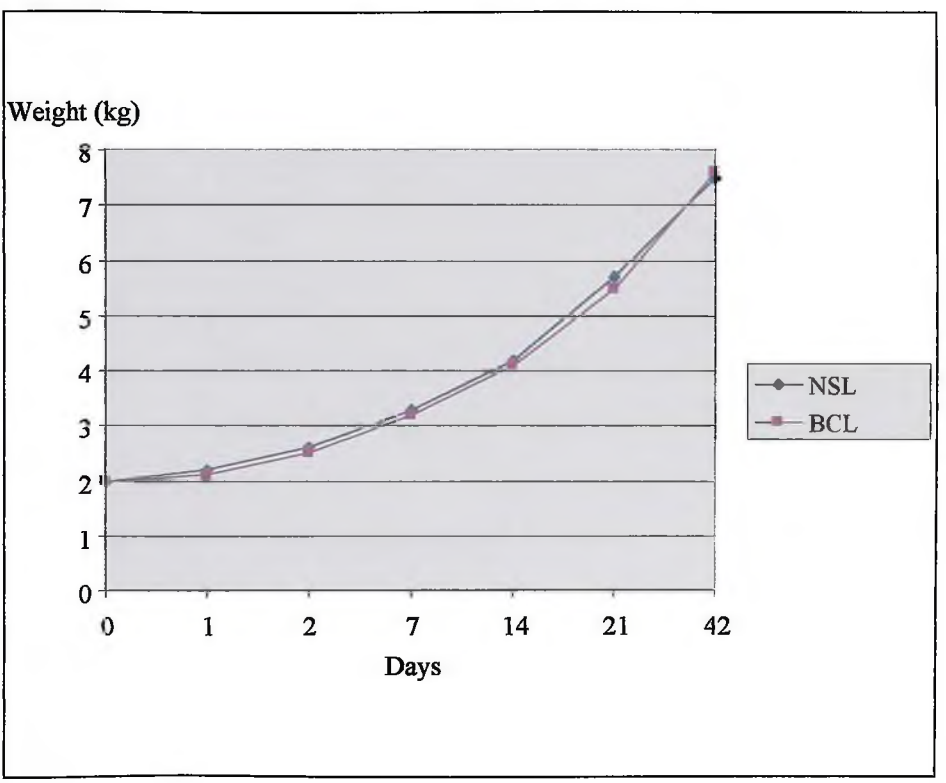
4.3 Birth weight, weaning weight and weight gain in Lambs

The weaning weights for the normally suckled and the bovine colostrum-fed lambs at 42 days were 7.75 and 7.77 kg respectively. There were no significant differences ($P > 0.05$) in mean weight gain and weaning weight of both the normally suckled and the bovine colostrum-fed lambs.

Lambs fed on bovine colostrum and those that suckled their dams had similar growth rates during the first 6 wks of life (Fig.7).

Birth weight had no significant effect (P>0.05) on weaning weight in both the normally suckled and the bovine colostrum-fed lambs at the end of the experiment.

Figure 7: Pre-weaning growth (kg) of normally suckled and bovine colostrum-fed lambs



NSL: Normally suckled lambs (n = 23)

BCL: Bovine colostrum-fed lambs (n =33)

4.4 The effect of serum Ig concentration on pre-weaning mortality

Four out of the thirty-three lambs fed bovine colostrum and two of the normally suckled lambs died by the end of the first week (Table 3). All the deaths were attributed to starvation and acute dehydration due to rejection by their dams.

Table 3: Effect of body weight and serum immunoglobulin concentrations on mortality

Colostrum	Weight (kg)		Ig concentration (zst)		Mortality
	Birth	Mean wt.	Peak	Mean	
Ovine	1.00-1.50	3.16 [a]	33.86 [a]	19.93 [a]	1
	1.51-2.00	3.94 [a]	29.70 [b]	18.14 [a]	0
	> 2.00	3.13 [a]	30.33 [b]	16.75 [b]	1
Bovine	1.00-1.50	3.16 [a]	31.46 [a]	19.44 [a]	1
	1.51-2.00	3.74 [a]	32.36 [a b]	21.15 [a]	2
	> 2.00	4.00 [a]	33.29 [b]	21.93 [a]	1

: x – Mean : SE – standard error

Means with different superscripts in each column are statistically significant.

There was no correlation between peak serum Ig levels and mean serum Ig concentration and pre-weaning mortality since the six lambs which died had serum Ig concentrations higher than that of their counterparts which survived in both the normally suckled and bovine colostrum-fed lambs. Similarly, birth weight had no significant effect on lamb mortality in both experimental groups

4.5 Composition of Colostrum

4.5.1 The effect of species on the nutrient composition of colostrum

The nutrient composition of pooled samples from Sangas (SNG) and Friesian-Sanga crossbreds (SFC), and from Djallonke (DJK) and Nungua Blackhead (NBH) ewes are shown in Table 4. There were significant differences between the two species ($P<0.05$) for all parameters measured except magnesium, iron, manganese and copper (Table 4).

Table 4: The nutrient composition of ovine and bovine colostrum

Nutrients	Ovine colostrums (n=12)	Bovine colostrums (n=7)
Protein (%)	15.65 ± 1.68^{a}	12.98 ± 0.63^{b}
Total solids (%)	23.09 ± 2.28^{a}	17.64 ± 1.35^{b}
Phosphorus (mg/l)	17.25 ± 2.50^{a}	13.38 ± 3.06^{b}
Calcium (mg/l)	30.21 ± 1.47^{a}	33.71 ± 2.45^{b}
Magnesium (mg/l)	6.79 ± 0.26^{a}	6.86 ± 0.50^{a}
Sodium (mg/l)	29.10 ± 1.31^{a}	51.75 ± 1.75^{b}
Potassium (mg/l)	54.95 ± 1.70^{a}	62.85 ± 2.87^{b}
Iron (mg/l)	1.42 ± 0.09^{a}	1.35 ± 0.51^{a}
Zinc (mg/l)	2.55 ± 0.90^{a}	1.49 ± 0.55^{b}
Manganese (mg/l)	0.02 ± 0.01^{a}	0.01 ± 0.01^{a}
Copper (mg/l)	0.11 ± 0.05^{a}	0.08 ± 0.06^{a}

* Means arranged in rows with different superscripts are significantly different.

The results showed that the protein and total solids contents were significantly ($P<0.05$) higher in ovine colostrum than in bovine colostrum. The results of the mineral analysis of colostrum samples also revealed that species differences were significant ($P<0.05$) for almost all the major minerals studied. With the exception of phosphorus which was significantly higher in ovine colostrum (17.25 mg/l), bovine colostrum had significantly higher concentrations of calcium, sodium and potassium. Though the concentration of microminerals were higher in ovine colostrum only the concentration of zinc was statistically significant ($P<0.05$).

4.5.2 The effect of breed on the nutrient composition of colostrum in cattle and sheep

The nutrient composition of colostrum from Sanga and Sanga-Friesian cross-breds are shown on Table 5. The results showed that the Sanga-Friesian Crosses had higher total solids and protein contents (19.15 and 13.25%, respectively) than the pure Sanga breeds (16.11 and 12.89%, respectively). Among the macrominerals, phosphorus, sodium and potassium were significantly higher ($P< 0.05$) in the Sanga than in the Cross-breds.

The mean concentration of microminerals in the Sanga and the Sanga-Friesian cross-breds were not significantly different ($P> 0.05$). The Sanga-Friesian crosses had higher concentrations of iron (1.58 mg/l) in Table 5 than the Sanga colostrum (1.33 mg/l). The concentration of zinc was significantly higher ($P<0.05$) in the SNG.

Table 5: The effect of breed on the composition of nutrients in bovine colostrum

Nutrients	Sanga (n=4)	Sanga-Friesian (n=3)
Protein (%)	12.89 ± 0.91 [a]	13.25 ± 1.15 [a]
Total solids (%)	16.11 ± 1.24 [a]	19.15± 2.4 [b]
Phosphorus (mg/l)	17.08 ± 8.33 [a]	12.38 ± 3.31 [b]
Calcium (mg/l)	34.24 ± 4.84 [a]	33.30 ± 1.33 [a]
Magnesium (mg/l)	6.85 ± 0.31 [a]	6.37 ± 0.70 [a]
Sodium (mg/l)	59.75 ± 12.10 [a]	44.78 ± 8.97 [b]
Potassium (mg/l)	79.0 ± 10.80 [a]	51.70 ± 17.4 [b]
Iron (mg/l)	1.33 ± 0.08 [a]	1.48 ± 0.12 [a]
Zinc (mg/l)	2.33 ± 0.78 [a]	1.21± 0.27 [b]
Manganese (mg/l)	0.01 ± 0.01 [a]	0.01 ± 0.01 [a]
Copper (mg/l)	0.08 ± 0.06 [a]	0.08 ± 0.06 [a]

Means in rows with different superscripts are significantly different.

The nutrient content of colostrum from the two breeds of sheep are shown in Table 6. Colostrum from the Djallonke breed of sheep was significantly higher ($P<0.05$) in protein (17.38%) and total solids (24.71%) than the Nungua Blackhead (13.97% and 21.46%, respectively).

Table 6: The effect of breed on the nutrient composition ovine colostrum

Nutrients	Nungua Blackhead (n=5)	Djallonke (n=7)
Protein (%)	13.97 ± 1.03 [a]	17.38 ± 2.00 [b]
Total solids (%)	21.45 ± 1.46 [a]	24.71 ± 1.39 [b]
Phosphorus (mg/l)	21.23± 4.24 [a]	15.92 ± 2.64 [b]
Calcium (mg/l)	30.39 ± 1.62 [a]	30.10 ± 5.65 [a]
Magnesium (mg/l)	6.70± 0.36 [a]	6.89 ± 0.09 [a]
Sodium (mg/l)	27.13 ± 12.43 [a]	40.73 ± 3.31 [b]
Potassium (mg/l)	55.70 ± 14.60 [a]	61.25 ± 6.40 [a]
Iron (mg/l)	1.50 ± 0.57 [a]	1.33 ± 0.55 [a]
Zinc (mg/l)	2.79 ± 0.90 [a]	4.92 ± 2.28 [b]
Manganese (mg/l)	0.04 ± 0.01 [a]	0.02 ± 0.01 [a]
Copper (mg/l)	0.05 ± 0.05 [a]	1.03± 0.75 [b]

Means in rows with different superscripts are significantly different.

There were significant differences ($P<0.05$) in the concentrations of minerals in the Djallonke and the Nungua Blackhead colostrum. This was evident in the concentrations of sodium, zinc and copper which were higher in the Djallonke breed. Only the concentration of phosphorus was significantly ($P<0.05$) higher in Nungua Blackhead than the observed values for Djallonke.

Statistically significant correlations between concentrations of some of the individual nutrient elements were established (Appendix 6). Evaluation of the link between total solids and protein using correlation analysis revealed a statistically significant positive correlation between the two ($P<0.01$, $r = 0.971$). With the exception of sodium and potassium which were positively correlated and significant ($P<0.05$, $r = 0.537$), all the other major minerals were not significant ($P>0.05$). Highly significant positive correlations were observed between total solids and zinc ($P<0.05$, $r = 0.609$), total solids and copper ($P<0.05$, $r = 0.609$), protein and copper ($P<0.01$, $r = 0.818$) and protein and zinc ($P<0.01$, $r = 0.812$). Calcium and copper were positively correlated and significant ($P<0.05$, $r = 0.50$) whilst sodium and iron were negatively correlated ($P<0.05$, $r = -0.335$). Apart from zinc and copper in which significant ($P<0.01$, $r = -0.914$) negative correlation was observed, the correlations between other microminerals were not significant ($P>0.05$).

4.5.3 The effect of season on the composition of colostrum

The composition of nutrients in colostrum varied with season in the two species and breeds under investigation. For bovine colostrum, the total solids content was significantly higher ($P<0.05$) in the dry season than in the rainy season (Table 7). There were also significant differences ($P<0.05$) between the dry season composition of macrominerals with phosphorus and sodium higher in the dry season whilst calcium was higher in the rainy season. Apart from zinc, the seasonal variations between other microminerals were not significant ($P>0.05$).

Table 7: The effect of season on the composition of nutrients in bovine colostrum

Nutrients	Rainy season (n=7)	Dry season (n=7)
Protein (%)	12.36 ±0.32 [a]	13.78±0.35 [a]
Total solids (%)	16.19 ± 0.68 [a]	19.07 ± 1.23 [b]
Phosphorus (mg/l)	13.38 ± 1.53 [a]	21.08 ±3.18 [b]
Calcium (mg/l)	33.71± 2.17 [a]	30.82 ± 0.85 [b]
Magnesium (mg/l)	6.54 ± 0.17 [a]	7.16 ± 0.24 [a]
Sodium (mg/l)	51.88± 5.34 [a]	57.43 ± 4.35 [b]
Potassium (mg/l)	62.85± 11.35 [a]	67.85 ± 4.41 [a]
Iron (mg/l)	1.39± 0.08 [a]	1.53± 0.08 [a]
Zinc (mg/l)	1.49 ± 0.27 [a]	2.05 ± 0.50 [b]
Manganese (mg/l)	0.01 ± 0.01 [a]	0.02 ± 0.01 [a]
Copper (mg/l)	0.13 ± 0.01 [a]	0.03 ± 0.09 [a]

Means in rows with different superscripts are significantly different.

The effect of season on ovine colostrum is shown in Table 8. The results indicate that protein and total solids were significantly higher ($P<0.05$) in the dry season (16.79 and 24.01%, respectively) than in the wet season (14.56 and 21.16%, respectively). With the exception of magnesium, all the major minerals in ovine colostrum were significantly higher in the dry season. Among the micro minerals, the concentrations of zinc and copper in the dry season (5.16 mg/l and 1.02 mg/l respectively) were significantly higher than in the rainy season (2.55 and 0.14 mg/l respectively).

Table 8: The effect of season the composition of nutrients in ovine colostrum

Nutrients	Rainy season (n=7)	Dry season (n=5)
Protein (%)	14.56 ±0.84 [a]	16.79±1.23 [b]
Total solids (%)	21.16 ± 1.14 [a]	24.01 ± 0.96 [b]
Phosphorus (mg/l)	17.25 ± 1.25 [a]	19.40 ±2.78 [b]
Calcium (mg/l)	29.81± 0.74 [a]	32.67± 2.69 [b]
Magnesium (mg/l)	6.74 ± 0.19 [a]	6.85 ± 0.03 [a]
Sodium (mg/l)	29.10± 6.55 [a]	38.75 ± 3.70 [b]
Potassium (mg/l)	53.70± 8.47 [a]	63.25 ± 5.86 [b]
Iron (mg/l)	1.42± 0.05 [a]	1.41± 0.07 [a]
Zinc (mg/l)	2.55 ± 0.45 [a]	5.16± 0.50 [b]
Manganese (mg/l)	0.02 ± 0.01 [a]	0.03 ± 0.01 [a]
Copper (mg/l)	0.14 ± 0.01 [a]	1.02 ± 0.58 [b]

Means in rows with different superscripts are significantly different.

4.5.4 Effect of storage on the nutrient composition of bovine colostrum

The nutrient content of both fresh colostrum and colostrum stored for 6 months is shown in Table 9. Even though protein and total solids were higher in freshly collected colostrum the differences were not significant (P>0.05). Apart from phosphorus which was higher in stored colostrum, all the major minerals were higher in fresh colostrum than in the stored colostrum. However, only the concentrations of calcium and

was higher in stored colostrum, all the major minerals were higher in fresh colostrum than in the stored colostrum. However, only the concentrations of calcium and potassium were significantly higher (P>0.05) in the fresh colostrum. Apart from copper which was significantly higher in the fresh ovine colostrums, the analysis produced no significant (P>0.05) differences in the concentrations of microminerals in both the freshly collected and stored colostrum.

Table 9: The effect of storage on the composition of bovine colostrum

Nutrients	Fresh colostrum (n=7)	Stored colostrums (n=7)
Protein (%)	12.39 ± 1.00 [a]	9.95 ± 0.91 [a]
Total solids (%)	15.28 ± 1.42 [a]	14.58 ± 0.56 [a]
Phosphorus (mg/l)	13.98 ± 4.64 [a]	15.03 ± 1.42 [a]
Calcium (mg/l)	36.61± 4.89 [a]	19.37± 2.74 [b]
Magnesium (mg/l)	6.66± 0.31 [a]	6.10 ± 0.02 [a]
Sodium (mg/l)	65.75± 10.25 [a]	63.56 ± 3.62 [a]
Potassium (mg/l)	86.50± 3.54 [a]	58.26 ± 1.47 [b]
Iron (mg/l)	1.27± 0.05 [a]	1.29± 0.67 [a]
Zinc (mg/l)	1.92 ± 0.21 [a]	1.93 ± 0.36 [a]
Manganese (mg/l)	0.05 ± 0.00 [a]	0.02 ± 0.00 [a]
Copper (mg/l)	0.07± 0.06 [a]	0.02 ± 0.01 [b]

Figures with different superscripts across rows are significantly different.

CHAPTER FIVE

DISCUSSION

The present study examined bovine colostrum as an alternative source of providing immunoglobulins for lambs to ensure flexibility in controlled breeding systems. The lambs consumed all the bovine colostrum offered (about 70 ml per lamb) with little or no difficulty. Results from the study showed that neither the normally suckled lambs nor the bovine colostrum-fed ones had any measurable quantity of serum immunoglobulins before feeding. This indicates that lambs, like other neonates with epitheliochorial placentation, have no antibodies from their dam before birth and need to ingest colostrum to provide passive immunity. This is in agreement with the studies of Donovan *et al* (1986), Abban (1999) and Osei *et al* (unpublished), who reported that most farm animals obtain immunoglobulins only after birth through the ingestion of colostrum. This is in sharp contrast to primates (Hurley, 2001), rodents, cats, rabbits and dogs where immunoglobulins can be transferred across the placental barrier to the foetus (Butler *et al*, 1971; Klobassa *et al*, 1986). The results of the present study emphasised the importance of colostrum as the sole source of immunoglobulins for neonatal lambs.

The results from this work also showed that even though the mean serum immunoglobulin concentration of normally suckled lambs (21.01 zst units) was slightly higher than that of bovine colostrum-fed lambs (18.26 zst units), the difference was not statistically significant. This is an indication that the heterologous bovine immunoglobulin of the bovine colostrum was absorbed with similar efficiency as the homologous immunoglobulin of the ovine colostrum. Bovine colostrum, as indicated by Radostits and associates (1995) has been used successfully to improve the

survival rate of hysterectomy-produced artificially reared pigs; and for rearing goats free of caprine arthritis encephalitis.

The slightly higher mean serum immunoglobulin concentration of normally suckled lambs is consistent with the works of Knight and Leek (1973) who observed that ewe-fed lambs had higher levels of serum immuneglobulins than bottle-raised lambs. Selman and associates (1970) and Stott and associates (1979) attributed better efficiency of apparent absorption of IgG by calves allowed to nurse their dam to neural effects of the presence of the dam.

In the present work, the Ig level for the bovine colostrum-fed animals peaked at 12 hrs as against 24 hrs for the normally suckled lambs. Abban (1999) working at the same station with the same breeds of lambs obtained a similar result for normally suckled lambs. However, Osei and associates (unpublished) noted that peak serum immunoglobulin level for normally suckled lambs occurred at 18 hrs after ingestion of colostrum. In general, the peak serum immunoglobulin levels recorded by these workers were higher than what was observed in the present study. These differences might be due to seasonal variations. There is evidence that season has an effect on serum Ig levels (Shearer *et al*, 1992). Whilst Abban carried out his work in the major rainy season (April to June), the present work was carried out in the minor season (late August - October), a period characterised by cold and windy nights with occasional showers. Thus, these environmental factors might have contributed to the lower peak serum immunoglobulin levels recorded for both groups. Johnson and associates (1995) established that in Brazil, serum Ig levels were highest in Moxoto goats during the dry season (June to December) and lowest in the rainy season (January to May).

In general absorption of immunoglobulin from the small intestine of lambs is known to peak between 15 to 24 hrs postpartum (Klobassa *et al* 1986; Radostits *et al* 1995). The results obtained for the normally suckled lambs fall within this range. The rapid increase in serum immunoglobulin concentration of bovine colostrum treated animals during the first 6 hrs of life with a peak at 12 hrs falls outside this range. The rapid increase in the absorption of immunoglobulins from the bovine colostrum could be attributed to the quantity of bovine colostrum administered at first feeding. Constant and associates (1994) revealed that kids fed low levels of IgG (1.5 g) per kilogram body weight had peak concentration at 24 hrs whereas those fed on higher levels of IgG (3 g) per kg body weight attained peak serum immunoglobulin concentration at 12 hrs. This implies that animals fed adequate amount of good quality colostrum at an early age are most likely to absorb and attain early peak immunoglobulin concentration and hence invariably possess early defensive mechanism. It is quite evident from this work that the absorption of gammaglobulins from the alimentary tract appears to have ceased after 12 hrs in bovine colostrum-fed lambs. This is in contrast to the normally suckled lambs in which cessation occurred after 24 hrs postpartum. Lambs are able to absorb gammaglobulin over a longer period after birth. Moreover, Ducker and Fraser (1976) noted that any limited period for the absorption of gammaglobulin from the alimentary tract of lambs begins from the time of first feeding rather than from the time of birth. This is contrary to findings in new born calves in which the rate of absorption was shown to decrease from birth and virtually ceased by about 18 hrs after birth. The early gut closure observed in the case of the bovine colostrum-fed lambs could be attributed to the heterologous bovine colostrum which ilicits early gut closure in the lambs. It was also observed that lambs fed with bovine colostrum passed more

meconium (the first thick mucus-like stool passed by the neonate after birth; consisting of desquamated cells, bile salts etc that collect in the intestine of the foetus and forms the first faecal discharge of the newborn) than the normally suckled ones.

There was no significant difference in serum Ig concentration in both the Djallonke and the Nungua Blackhead lambs in the two treatment groups. The peak serum immunoglobulin levels of the bovine colostrum-fed Djallonke lambs was higher than the Nungua Blackhead lambs. Studies have shown that breed has an effect on peak serum Ig levels in neonates (Muller and Elinger, 1981; Roy, 1990; Abban, 1999). In the present study, the Ig level fell much more rapidly in the Nungua Blackhead (NBH) lambs than in the Djallonke (DJK) lambs. In contrast, Abban (1999) found that the rate of decline was more rapid in the Djallonke breed.

Studies on the effect of sex on Ig levels have been inconsistent. For instance, in piglets Awotwi and associates (2000), found that Large White females had higher peak Ig than the males whereas the reverse was true for Ashanti Black piglets. Vann and associates (1995), found no effect of calf gender on Ig absorption. On the other hand, Roy (1990) reported that heifer calves had higher Ig concentration than bull calves. The present study revealed that ewe lambs in the bovine colostrum-fed group had higher peak serum immunoglobulin levels than their male counterparts in the same group, thus supporting the pattern observed in calves (Roy, 1990) and Large White piglets (Awotwi *et al*, 2000) in which females had higher peak Ig levels.

The results from this work also established that normally suckled lambs with lower birth weights (1.00 – 1.50 kg) had higher mean and peak serum Ig concentrations than those with high birth weights (> 2.00 kg). This is in agreement with the results of

Quigley and associates (2002) who observed that animals with high birth weights tend to have lower Ig concentrations due to their larger serum/plasma pool. In contrast, birth weight had no effect on mean Ig concentration in bovine colostrum-fed lambs. This might be due to the large volume of colostrum fed to each animal , since each lamb was allowed to suckle as much colostrum as it could.

There was no significant difference between the pre-weanung growth rates of both the normally suckled and the bovine colostrum-fed lambs. Both groups had similar growth pattern. The present findings do not support the work of Vihan (1986) who observed that body weight gain was highest in ewe-raised than in bottle-raised lambs. Low growth rates in bottle-fed lambs are normally attributed to low initial intake of colostrum resulting in late absorption of gammaglobulins. In the present study however, the serum immunoglobulin levels for the bovine colostrum-fed (bottle-fed) lambs peaked earlier than that for the normally suckled lambs, suggesting that there was no delayed intake of colostrum. This supports the argument of Besser and associates (1991) that artificial feeding allows the farmer to regulate the volume of colostrum ingested as well as the time after birth when colostrum is fed, thus reducing the prevalence of failure of passive transfer compared with natural feeding.

Two out of the 23 normally suckled lambs (8 70%) and four of the bovine colostrum-fed ones (12.12%) died before the end of the first week of life. Four of the six lambs died through rejection (mismothering) and belonged to primiparous ewes. Ewes lambing for the first time are more easily disturbed than those that have lambed before probably due to the stress and pain of parturition. Disturbances of maternal behaviour are known to contribute to a considerably high rate of neonatal lamb mortality

(Alexander *et al*, 1984). Similar observations were made in young mares (Arnold, 1985) and in cows (Hulet *et al*, 1975).

Lamb mortality prior to weaning could not be attributed to failure of passive transfer since some of the dead lambs had higher Ig concentrations than most of their counterparts that survived (Append. 1). The minimum serum immunoglobulin (zst) value consistent with neonatal lamb survival is not well documented. Fisher *et al* (1976) observed that Salmonellosis will affect calves irrespective of passive immune status or if they have specific antibodies against Salmonellae. Reid (1972) recorded deaths from Colisepticaemia in lambs with less than 10 zst units. Fey (1972) suggested similar values for calves. In the present study, the lowest Ig concentration in an individual lamb was 7.9 zst units which falls below the level suggested by Reid (1972), but within the range (6 – 15 zst) required for minimal protection (Radostits and Blood, 1994). Incidentally, this lamb survived and was weaned successfully.

The factors that determine morbidity and mortality in neonatal farm animals are complex and inter-related. Apart from the amount and quality of colostrum ingested and the immune globulins absorbed (Besser and Gay, 1994), the level of management, the spectrum of pathogens in the environment as well as the level of sanitation and hygiene provided the neonate are other factors that can affect neonatal mortality (Radostits and Blood, 1994). The nature and severity of environmental stressors (Olson *et al*, 1980) like ambient temperature (especially for piglets and lambs), the size of the herd and the maternal behaviour are other obvious factors that come into play.

The mammalian neonate's requirement for nutrients must be met by dietary sources or body stores, and usually the dietary source is supplied by colostrum/milk from the dam. According to Bruhn (1998), it appears that the primary requirements for feeding colostrum is disease protection, hence the nutritional benefit from feeding colostrum to the young is often overlooked, possibly due to a lack of direct link between the nutritional composition and improved health in neonates.

The nutritional analysis revealed that the mean total solids and protein were significantly higher in ovine colostrum (22.16 and 14.56% respectively) than in bovine colostrum (16.21 and 12.36% respectively). The percentage protein and total solids observed in the present study are lower than those reported by Foley and associates (1972) and Kume and others (2003) for bovine colostrum. Foley and associates (1972) reported values of 21.32 and 28.30% for bovine colostrum, whilst the values for protein and total solids in normal milk of cows were quoted as 3.34 and 12.86%, respectively. The high levels of protein and total solids in colostrum can be attributed to the higher concentrations of immunoglobulins and other immune factors (Mellor and Murray, 1985; Tonk, 1995). Indeed, studies by Wastra and Jenness (1984) showed that bovine colostrum had a protein level as much as four times that of of normal milk and that most of these proteins were immunoglobulins.

The higher nutrient content of the ovine colostrum compared to that of bovine is similar to results obtained by Bobb (1999) who found that bovine colostrum had 20 to 40% less nutrients than ewe colostrum. Even in normal milk, IDF (1983) and Saini and Gill (1991) established that sheep milk was superior to bovine milk in protein content.

Payne (1992) stated that the same nutrients are present in the milk of all species but in different proportions and that the composition differs between species.

Apart from the species, environmental factors such as temperature and humidity can also affect colostrum composition (Nardone *et al*, 1997). The time of colostrum collection can also affect its composition. In the present work all the samples were collected within the first 6 hrs postpartum. Results obtained by Lazaro (2002) showed that bovine colostrum from first milking immediately after parturition had higher protein and total solids than samples collected 18 hrs after parturition.

The mean concentration of macroelements (Ca, P, Mg, Na and K) observed in bovine colostrum were higher than that reported by other workers for temperate breeds (Sebela *et al*, 1976; Walkiewicz, 1979). The values of Ca, Na and K were significantly higher than the corresponding values in ovine colostrum. The concentration of P was however higher in ovine colostrum. According to Van der Berg (1990) differences in the mineral composition of colostrum could be related to the species and breed. Studies have shown that the bone-forming minerals, Ca and P, are generously provided in the colostrum in a ratio comparable to that in normal milk; thus making them suitable for effective absorption and utilization (Voutsinas *et al* 1990). The main sources of minerals found in milk/colostrum are food, water and body stores. About 10-15% of milk Ca for instance comes from maternal stores (Van der Berg, 1990). Thus Ca and for that matter P are transferred directly from maternal serum to colostrum/breast milk; hence, their concentrations do not fluctuate with maternal dietary intake. Their concentrations in the present study therefore could not be equated solely to their levels in the prepartum diet. The high level of potassium and sodium in the colostral samples

was consistent with the observations of Baranow-Baranowski and Bronisz (1979) that both minerals were higher in colostrum than in milk. It also reaffirms the assertion by Van der Berg (1990) that during the period of early life when milk is the only source of food for the neonate, K is equal in importance to the bone-forming minerals and that the body at this stage contains more K than Na. The low levels of some macrominerals (P and Mg) reported in this study supports the works of Walkiewicz (1979) and Haenlein (2002) who reported lower contents of these minerals.

The concentrations of microminerals (Fe, Zn, Mn and Cu) in both bovine and ovine colostrum were generally lower than reported by other workers (Roy, 1980; Muehlenbein *et al,* 2001). The level of Fe however was higher than the 0.37mg/l reported by Sebela and others (1976). The low level of iron, for example accounts for infantile anaemia that is observed in several neonates (Bruhn, 1999). The concentrations of Cu (0.07mg/l) observed in the present study were lower than values reported (0.6mg/l and 0.34mg/l) for bovine colostrum by other workers (Roy, 1980; Pavlata, 2004). In general, the concentrations of microminerals observed in ovine colostrum were higher than those observed in bovine colostrum.

Several studies have shown that the level of microminerals in colostrum are generally very low (Wooliams *et al,* 1996). Cambell and Marshall (1975) suggested that higher levels of Fe and Cu in colostrum will be destructive to certain vitamins and would catalyze oxidation thereby producing a metallic or oxidized flavour. In general the low levels of these nutrients in colostrum could be attributed to inadequate sources/supplementation of these nutrients in late pregnancy. Beyond meeting the daily requirements of the animal, it is of special interest to pay attention to

composition and quantity of the diet during the last three weeks prior to parturition since this can cause changes in the composition of the colostrum, especially the micromineral contents.

In addition to the species differences, the composition of colostrum also varied with breed. Colostrum from the Sanga-Friesian crosses was higher in total solids (19.15%) and protein (13.25%) than colostrum from the pure Sanga breeds (16.11 and 12.89% respectively). Similarly colostrum from the Djallonke breed of sheep was higher in the above components than the Nungua Blackhead colostrum (ie 24.71% solids and 17.38% protein as against 21.46% total solids and 13.97% protein). Besides, both the Sanga and the Djallonke breeds had higher concentrations of macrominerals than their respective counterparts except in the case of P which was higher in the Nungua Blackhead sheep. High milk producing animals are known to produce milk with lower nutrient contents (Quigley *et al* 1994). The higher protein and total solids content of colostrum from the Friesian-Sanga crosses could be due to the fact that they are stall-fed throughout the year with fresh or ensiled sorghum and P*anicum* in addition to concentrates as opposed to the Sanga, which are grazed entirely throughout the year. Quigley and Drewry (1998) reported that the prodution of milk protein could be increased when cows are fed ruminally protected protein or amino acids. The higher nutrient content of the Djallonke breed could not be attributed to nutrition since both breeds are kept under the same management system and nutrional regime. The difference might be purely due to breed.

There was a highly significant positive correlation between the total solids and protein in colostrum (Append. 6). This finding is in agreement with the results of Brendehaug

and Abrahamsen (1986) who reported positive correlation between total solids and protein in the milk of Norwegian goats.

The correlations between Ca and protein as well as Mg and protein were observed to be positive but not statistically significant. This is inconsistent with the findings of Jenness (1980), Storry and others (1983) and Voutsinas and associates (1990) who reported highly significant positive correlations between the two minerals and protein in ordinary milk. Phosphorus and protein, though positively correlated were not significant. In addition Ca and P, and Ca and Mg were negatively correlated but not significant. All these findings are in agreement with those of Storry *et al* (1983).

Seasonal variations characterized the composition of the major nutrients in colostrum from both cattle and sheep. The results of the present study showed that protein and total solids of ovine colostrum were significantly higher in the dry season. In bovine colostrum only the total solid was significantly higher in the dry season. Johnson and associates (1995) reported that Ig levels are highest in the dry season and lowest in the rainy season. Several environmental factors including temperature and humidity are known to affect colostrum quality. For instance, Nardone and associates (1997) reported that heifers exposed to high temperatures with high humidity produced colostrum with lower crude protein and IgG than heifers maintained in thermoneutral environment.

The results also show that whilst bovine colostrum contain higher concentration of Ca in the rainy season, the macrominerals, with the exception of P, were significantly higher in the dry season. While the concentrations of Mg invariably remained stable

over both seasons for the two species, P concentration in bovine colostrum was highly elevated in the dry season. Similarly, with regard to the microelements, significantly higher concentrations were observed in the dry season. These variations were more pronounced in zinc and copper concentrations than in iron and manganese concentrations. These findings are in contrast to results obtained by Sugeil *et al* (1989), who found that season had no effect on the concentrations of iron, copper, zinc and chlorine in colostrum. In Ghana and most other sub-Saharan African countries, the nutritional quality of forages is poor during the dry season. It was therefore expected that in the dry season the nutrient content might be lower. The higher nutrient content of the dry season colostrum might have been due to concentration of nutrients in the colostrum since less water is secreted into it thus reducing the extent of dilution. This is an attempt by the animals to conserve water.

The study also revealed no significant ($P>0.05$) difference in the protein and total solids composition in the fresh and stored colostrum. Since gammaglobulins are found mostly in the protein portion of the colostrum, it could be concluded that the colostral samples could still maintain their immune properties after six months in storage. This reinforces earlier findings (Waterman, 1997; Quigley *et al,* 1998) that colostrum could be stored in the deep freezer up to a year without any appreciable change in concentrations of immunoglobulins. The results also demonstrated that the concentration of calcium and potassium in colostrum declined drastically with storage whilst the concentration of phosphorus increased. The reason for the elevated phosphorus concentration in the stored colostrum was not quite clear. The micromineral concentrations in the fresh colostrum were not affected by storage.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The study confirmed the fact that lambs, like other ruminants, are born agammaglobinaemic and require some days to develop the ability to produce active immunity to pathogenic organisms. Hence, adequate transfer of maternal immunoglobulins to lambs through colostrum is a key factor to limiting neonatal disease and thrift.

The results showed that:

(i) The serum immunoglobulin concentration in the bovine colostrum-fed lambs peaked earlier (12 hrs) than the normally suckled lambs (24 hrs) indicating that closure in bovine colostrum-fed lambs occurred earlier than in the normally suckled ones.

(ii) The normally suckled and the bovine colostrum-fed lambs had similar growth patterns.

(iii) Breed and sex had no significant effect in the absorption of serum Ig in both the normally suckled and the bovine colostrum-fed lambs.

(v) Mortality rates were not different between the two groups of lambs.

(vii) Ovine colostrum contained higher protein, total solids, phosphorus, zinc and copper whilst bovine colostrum was higher in calcium, sodium and potassium.

(viii) Breed had no significant effect on the nutrient composition of bovine colostrum.

(ix) Colostrum collected in the dry season was slightly higher in nutrients than that collected in the rainy season.

Based on the results of the study, it is concluded that bovine colostrum can be used effectively as a reliable alternative source of Ig for lambs. It is therefore recommended that:

: Orphan lambs and rejected lambs as well as lambs whose dams fail to lactate normally should be fed adequate quantity of bovine colostrum within the first 12 hrs of life.

: Breed of cattle had very little effect on the nutrient composition of colostrum hence colostrum could be collected from any of the breeds available.

: Bovine colostrum should be collected within the first 6 hrs postpartum and stored in small quantities in a deep-freezer for future use.

: Bovine colostrum could be stored in small quantities in a deep-freezer for up to six months without any deterioration in immunoglobulin concentrations.

: Colostrum meant for feeding lambs should ideally be collected in the dry season since the nutritional content of colostrum appears to be higher in the dry season than in the wet season.

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Serum immunoglobulin (Ig) concentration of lambs fed Ovine colostrum (normally suckled)

Appendix 1A

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
1221	BH	R/L	0	22	32	40	30	26	20	14	9	24.10
1211	FT	E/L	0	9	19	26	18	19	19	20	20	18.8
1243	FT	R/L	0	10	19	25	22	16	14	12	10	16.0
1263	FT	R/L	0	-	29	19	22	14	11	10	10	16.4
1215	FT	R/L	0	4	31	40	32	30	30	29	29	28.1
1224	BH	E/L	0	0	19	24	-	26	11	13	9	14.6
1222	FT	E/L	0	26	32	30	28	19	16	10	4	20.9
1228	BH	E/L	0	-	20	29	21	16	19	14	9	19.4
903	DJK	E/L	0	19	32	30	37	36	27	24	24	28.6
932	DJK	E/L	0	18	16	32	30	26	20	25	30	24.6
933	DJK	R/L	0	8	26	40	40	18	19	13	19	22.9
996	DJK	E/L	0	12	0	24	34	27	30	23	-	22.4
822	DJK	E/L	0	16	42	38	38	32	38	36	19	32.4
*918	NBH	R/L	0	14	20	22	24	33	18	14	8	14.6*
928	DJK	E/L	0	-	18	24	11	28	-	22	14	25.5
559	NBH	R/L	0	4	20	26	31	-	20	17	2	17.2
972	NBH	R/L	0	22	18	23	28	29	16	14	4	19.5
*967	DJK	R/L	0	8	18	13	23	10	-	8	-	15.3*
973	DJK	R/L	0	14	17	22	20	36	30	18	20	22.1
830	NBH	R/L	0	20	40	36	38	22	27	38	8	28.4
810	DJK	R/L	0	20	24	17	28	14	8	10	12	16.6
931	NBH	E/L	0	6	14	23	33	19	24	12	4	16.9
Mean			*0*	*13.2*	*22.1*	*26.7*	*30.2*	*25.6*	*3.5*	*19.4*	*14.2*	*22.1*
Sd			0	6.38	10.4	7.6	8.1	8.0	7.7	8.8	8.6	5.3
S e			0	1.7	2.7	2.0	2.1	2.1	2.1	2.3	2.4	1.4

DJK = Djallonke E/L = Ewe Lamb NBH = Nungua Blackhead RL = Ram Lam

* Died before weaning

Appendix 1B

Serum immunoglobulin (Ig) concentrations in lambs fed with bovine colostrum (bottle-fed)

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
1250	BH	E/R	0	12	21	28	17	18	18	19	20	19.3
1251	FT	E/L	0	6	10	10	19	17	14	11	8	11.9
1253	FT	R/L	0	26	28	8	20	16	12	10	6	15.8
1255	FT	R/L	0	13	19	10	18	16	14	11	10	13.9
1256	FT	E/R	0	48	40	32	9	14	16	18	20	24.6
1257	BH	E/L	0	30	30	34	20	19	18	17	18	23.1
*1258	BH	R/L	0	40	30	10	24	18	17	9	4	19.0*
*1260	BH	R/L	0	8	6	36	15	-	12	16	10	14.7*
1262	FT	E/L	0	8	32	24	30	18	16	14	12	19.3
959	DJK	E/L	0	10	20	17	15	21	17	11	13	15.5
960	DJK	R/L	0	4	14	27	18	11	19	13	13	14.9
961	DJK	R/L	0	4	24	16	20	14	11	8	12	13.6
940	NBH	R/L	0	10	12	8	26	21	16	10	8	13.9*
*990	NBH	R/L	0	18	29	17	10	14	11	18	12	16.1*
911	NBH	R/L	0	30	12	32	26	37	26	22	18	25.4
912	NBH	R/L	0	26	-	19	38	-	15	-	6	20.8
2208	DJK	R/L	0	4	24	16	20	14	11	8	12	13.6
913	DJK	E/L	0	18	42	-	31	-	23	26	17	26.2
920	DJK	E/L	0	4	40	22	19	26	28	16	10	20.6
934	DJK	R/L	0	10	20	28	20	22	16	-	28	20.6
840	*NBH	E/L	0	20	24	17	13	10	14	11	12	15.1*
917	DJK	E/L	0	42	24	20	20	16	22	18	16	22.3
914	DJK	E/L	0	12	18	33	36	26	-	16	29	24.3
948	DJK	R/L	0	11	18	13	20	16	14	13	3	13.5
929	DJK	E/L	0	19	37	42	32	20	18	17	20	25.6
946	DJK	R/L	0	14	40	36	28	10	20	14	8	21.3
995	DJK	E/L	0	4	28	26	18	10	16	16	12	16.3
971	DJK	E/L	0	16	24	30	28	-	14	14	17	20.4
$\bar{X}$			0	17.3	24.7	21.7	21.9	17.1	16.6	13.9	12.2	18.4
Sd			0	11.0	11.3	10.6	9.0	7.7	7.1	6.2	7.4	5.9
Se			0	2.4	2.4	2.2	1.8	1.9	1.5	1.3	1.5	1.2

DJK = Djallonke E/L = Ewe Lamb

NBH = Nungua Blackhead RL = Ram Lamb

* Died before weaning

Appendix 1C

Serum immunoglobulin concentration in Djallonke and Nungua Blackhead lambs normally suckled

Djallonke

lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
905	DJK	E/L	0	4	26	31	38	28	28	17	20	24.0
903	DJK	E/L	0	19	32	30	37	36	27	24	24	28.6
932	DJK	E/L	0	18	16	32	30	26	20	25	30	24.6
933	DJK	R/L	0	8	26	40	40	18	19	13	19	22.9
996	DJK	E/L	0	12	0	24	34	27	30	23	-	22.4
822	DJK	E/L	0	16	42	38	38	32	38	36	19	32.4
928	DJK	R/L	0	-	18	24	11	28		22	14	25.5
967	DJK	R/L	0	8	18	13	23	10		8		15.3
973	DJK	R/L	0	14	17	22	20	36	30	18	20	22.1
810	DJK	R/L	0	20	24	17	28	14	8	10	12	16.6
$\bar{X}$			*0*	*12.5*	*21.9*	*27.1*	*29.9*	*29.1*	*25.0*	*19.6*	*15.8*	

Nungua Blackhead

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
918	NBH	R/L	0	14	20	22	24	33	18	14	8	14.6
559	NBH	R/L	0	4	20	26	31		20	17	2	17.2
972	NBH	R/L	0	22	18	23	28	29	16	14	4	19.5
830	NBH	R/L	0	20	40	36	38	22	27	38	8	28.4
931	NBH	E/L	0	6	14	23	33	19	24	12	4	16.9
$\bar{X}$			*0*	*13.2*	*22.4*	*26.0*	*30.8*	*25.3*	*21.0*	*19.0*	*5.2*	*22.1*

Appendix 1D

Serum immunoglobulin concentration in male and female lambs normally suckled by their dams

Female

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
905	DJK	E/L	0	4	26	31	38	28	28	17	20	24.0
903	DJK	E/L	0	19	32	30	37	36	27	24	24	28.6
932	DJK	E/L	0	18	16	32	30	26	20	25	30	24.6
996	DJK	E/L	0	12	0	24	34	27	30	23		22.4
822	DJK	E/L	0	16	42	38	38	32	38	36	19	32.4
928	DJK	E/L	0	-	18	24	11	28	-	22	14	25.5
931	NBH	E/L	0	6	14	23	33	19	24	12	4	16.9
$\bar{X}$			*0*	*14.4*	*21.1*	*28.9*	*31.6*	*28.0*	*27.8*	*22.7*	*18.5*	*22.1*

Male

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
933	DJK	R/L	0	8	26	40	40	18	19	13	19	22.9
918	NBH	R/L	0	14	20	22	24	33	18	14	8	14.6
559	NBH	R/L	0	4	20	26	31		20	17	2	17.2
972	NBH	R/L	0	22	18	23	28	29	16	14	4	19.5
967	DJK	R/L	0	8	18	13	23	10	-	8		15.3
973	DJK	R/L	0	14	17	22	20	36	30	18	20	22.1
830	NBH	R/L	0	20	40	36	38	22	27	38	8	28.4
810	DJK	R/L	0	20	24	17	28	14	8	10	12	16.6
$\bar{X}$			*0*	*13.8*	*22.9*	*24.9*	*29.0*	*23.4*	*23.0*	*16.5*	*10.4*	*22.1*

Appendix 2A

Serum immunoglobulin concentration of lambs bottle-fed with bovine colostrum

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
	DJK		0	32	44	40	36	30	36	28	19	
992	DJK	R/L	0	12	18	21	8	10	13	7	6	11.9
981	DJK	E/L	0	10	8	15	12	8	4	6	0	7.9
994	DJK	E/L	0	18	24	9	6	12	10	8	6	11.6
910	DJK	R/L	0	32	6	0	18	12	10	8	4	11.3
959	DJK	E/L	0	10	20	17	15	21	17	11	13	15.5
960	DJK	R/L	0	4	14	27	18	11	19	13	13	14.9
961	DJK	R/L	0	4	24	16	20	14	11	8	12	13.6
913	DJK	E/L	0	18	42		31		23	26	17	26.2
920	DJK	E/L	0	4	40	22	19	26	28	16	10	20.6
934	DJK	R/L	0	10	20	28	20	22	16		28	20.6
917	DJK	E/L	0	42	24	20	20	16	22	18	16	22.3
914	DJK	E/L	0	12	18	33	36	26	-	16	29	24.3
948	DJK	R/L	0	11	18	13	20	16	14	13	3	13.5
929	DJK	E/L	0	19	37	42	32	20	18	17	20	25.6
946	DJK	R/L	0	14	40	36	28	10	20	14	8	21.3
995	DJK	E/L	0	4	28	26	18	10	16	16	12	16.3
971	DJK	E/L	0	16	24	30	28	-	14	14	17	20.4
$\bar{X}$			*0*	*15.4*	*25.9*	*24.2*	*22.4*	*18.5*	*17.9*	*14.2*	*13.5*	*22.1*

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\bar{X}$
840	**NBH**	E/L	0	20	24	17	13	10	14	11	12	15.1
981	**NBH**	E/L	0	10	8	15	12	8	4	6	0	7.9
940	**NBH**	R/L	0	10	12	8	26	21	16	10	8	13.9
943	**NBH**	R/L	0	39	41	12	28	14	8	5	4	19.3
990	**NBH**	R/L	0	18	29	17	10	14	11	18	12	16.1
911	**NBH**	R/L	0	30	12	32	26	37	26	22	18	25.4
912	**NBH**	R/L	0	26	-	19	38	-	15		6	20.8
$\bar{X}$			*0*	*21.9*	*21*	*17.1*	*21.9*	*18.3*	*13.4*	*13.0*	*8.6*	*22.1*

Appendix 2B

Serum Ig concentration of male and female lambs fed with bovine colostrums

Male Lambs

Lamb	Breed	Sex	0	6	12	18	24	30	36	42	48	$\overline{X}$
	DJK	R/L	0	32	44	40	36	30	36	28	19	33.1
992	DJK	R/L	0	12	18	21	8	10	13	7	6	11.9
910	DJK	R/L	0	32	6	0	18	12	10	8	4	11.3
940	NBH	R/L	0	10	12	8	26	21	16	10	8	13.9
943	NBH	R/L	0	39	41	12	28	14	8	5	4	19.3
960	DJK	R/L	0	4	14	27	18	11	19	13	13	14.9
961	DJK	R/L	0	4	24	16	20	14	11	8	12	13.6
990	NBH	R/L	0	18	29	17	10	14	11	18	12	16.1
911	NBH	R/L	0	30	12	32	26	37	26	22	18	25.4
912	NBH	R/L	0	26		19	38		15	-	6	20.8
934	DJK	R/L	0	10	20	28	20	22	16		28	20.6
948	DJK	R/L	0	11	18	13	20	16	14	13	3	13.5
946	DJK	R/L	0	14	40	36	28	10	20	14	8	21.3
$\overline{X}$			*0*	*18.6*	*23.2*	*20.7*	*22.8*	*18.3*	*16.5*	*15.0*	*10.4*	*22.1*

Female Lambs

Lambs	Breed	Sex	0	6	12	18	24	30	36	42	48	$\overline{X}$
992	DJK	E/L	0	10	8	15	12	8	4	6	0	11.9
994	DJK	E/L	0	18	24	9	6	12	10	8	6	11.6
840	NBH	E/L	0	20	24	17	13	10	14	11	12	15.1
959	DJK	E/L	0	10	20	17	15	21	17	11	13	15.5
913	DJK	E/L	0	18	42		31		23	26	17	26.2
920	DJK	E/L	0	4	40	22	19	26	28	16	10	20.6
917	DJK	E/L	0	42	24	20	20	16	22	18	16	22.3
914	DJK	E/L	0	12	18	33	36	26		16	29	24.3
929	DJK	E/L	0	19	37	42	32	20	18	17	20	25.6
995	DJK	E/L	0	4	28	26	18	10	16	16	12	16.3
971	DJK	E/L	0	16	24	30	28		14	14	17	20.4
$\overline{X}$			*0*	*15.7*	*26.2*	*23.5*	*20.9*	*18.1*	*15.6*	*14.5*	*13.8*	*22.1*

Appendix 3A

Body weight and concentration of Ig in normally suckled Lambs

Group (Birth Wt)	Body weight				Serum Ig concentration		
	At Birth x sd	At weaning x sd	Gain x sd	Mean x sd	Minimum x sd	Maximum x sd	Mean x sd
1.00-1.50 kg	1.26 0.25	7.38 2.43	5.02 3.25	3.16 0.90	6.0 3.94	31.4 5.81	19.44 3.43
1.51-2.00 kg	2.00 0.00	7.55 0.69	5.55 0.69	3.94 0.46	8.73 4.52	32.36 5.68	21.15 5.38
>2.00 kg	2.47 0.08	7.75 0.52	4.8 1.37	4.13 0.26	8.43 6.53	33.29 6.63	21.93 5.73

Appendix 3B

Body weight and concentration of Ig in serum of bovine colostrum-fed Lambs

Group (Birth Wt)	Body weight				Serum Ig concentration		
	At Birth x sd	At weaning x sd	Gain x sd	Mean x sd	Minimum x sd	Maximum x sd	Mean x sd
1.00-1.50	1.50 0.00	6.92 1.96	4.71 2.58	3.16 0.91	11.86 5.24	33.86 7.93	19.93 4.26
1.51-2.00	1.98 0.06	7.86 1.58	5.33 2.28	3.74 0.80	8.55 4.73	29.7 11.38	18.14 5.96
>2.00	2.00 0.00	8.10 0.55	4.73 2.18	4.00 0.54	5.50 4.55	30.33 7.61	16.75 5.30

Appendix 4

Composition of nutrients in colostrum

Nutrients	NBH (n = 5)	DJK (n = 7)	SNG (n = 4)	SFC (n = 3)
Protein %	12.63 - 14.81	15.64 - 19.81	11.68 – 13.87	12.03 – 14.61
Mean ± SD	13.97 ± 1.03	17.38 ± 2.00	12.89 ± 0.91	13.25 ± 1.15
CV	0.074	0.115	0.071	0.087
Total Solids %	19.71 – 23.13	23.11 – 26.47	14.32 – 16.89	16.68 – 21.42
Mean ± SD	21.45 ± 1.46	24.71 ± 1.39	16.11 ± 1.24	19.15 ± 2.4
CV	0.068	0.056	0.077	0.125
Phosphorus	16.30 – 26.52 20	13.14 - 18.46	10.70 – 30.60	11.17 – 18.58
Mean ± SD	73 ± 4.24	15.92 ± 2.64	15.57±	15.38 ± 3.31
CV	0.205	0.166		0.215
Calcium	28.76 – 31.93	28.87 – 40.56	29.21 – 40.07	30.36 – 33.21
Mean ± SD	30.39 ± 1.62	32.10 ± 5.65	33.24 ± 4.84	31.30 ± 1.33
CV	0.053	0.176	0.146	0.042
Magnesium	6.16 – 6.92	6.79 – 6.98 6.89	76.44 – 7.19	6.13 – 7.81 6.37
Mean ± SD	6.70 ± 0.36	± 0.09 0.013	6.85 ± 0.31	± 0.70 0.110
CV	0.054		0.045	
Sodium	11.6 – 42.0	38.64 – 42.43	29.21 – 75.0	34.36 – 54.6
Mean ± SD	27.13 ± 12.43	40.73 ± 3.31	59.75 ± 12.10	44.78 ± 8.97
CV	0.759	0.081	0.045	0.200

Potassium	30.80 – 75.0	52.0 – 66.0	64.0 – 89.0	28.8 – 70.6
Mean ± SD	55.70 ± 20.60	61.25 ± 6.40	79.0 ± 10.80	51.70 ± 17.4
CV	0.370	0.104	0.137	0.337
Iron	1.43-1.58	1.26-1.37	1.23-1.78	1.44-1.70
Mean ± SD	1.5 ± 0.066	1.33 ± 0.051	1.33 ± 0.084	1.58 ± 0.108
CV	0.044	0.039	0.063	0.068
Zinc	2.285-3.3	1.39-8.83	1.775-3.49	0.813-1.375
Mean ± SD	2.79 ± 0.574	4.92 ± 3.278	2.33 ± 0.781	1.22 ± 0.266
CV	0.206	0.667	0.335	0.220
Manganese	0.29-0.39	0.005-0.022	0.005-0.018	0.005-0.015
Mean ± SD	0.04 ± 0.005	0.02 ± 0.008	0.01 ± 0.006	0.01 ± 0.005
CV	0.152	0.476	0.446	0.02 0.667
Copper	0.043-0.149	0.087-2.50	0.024-0.127	0.023-0.131
Mean ± SD	0.10 ± 0.055	1.03 ± 1.147	0.08 ± 0.056	0.08 ± 0.058
CV	0.565	1.114	0.748	0.748

- Concentration of minerals are in mg/l
- Means with different superscripts across rows are significantly different.
- SD refers to standard deviation.
- CV refers to coefficient of variation

Appendix 5A

Seasonal composition of nutrients in Cow and Ewe colostrum

WET SEASON

	Protein	Solids	P	Ca	Na	K	Mg	Fe	Zn	Mn	Cu
NBH	13.72	20.98	19.987	31.933	11.6	70	6.878	1.517	3.27	0.029	0.151
NBH	12.63	19.71	18.297	28.761	26.8	30.8	6.158	1.471	2.285	0.039	0.113
DJK	16.26	24.85	18.46	29.698	41	62	6.918	1.359	3.24	0.005	0.153
DJK	15.64	23.11	14.257	28.867	37	52	6.989	1.318	1.39	0.018	0.139
SNG	11.68	14.32	10.7	40.065	60	89	6.875	1.23	2.06	0.018	0.12
SNG	13.1	16.23	17.255	33.148	58.5	84	6.443	1.306	1.775	0.014	0.079
SFC	12.63	16.68	11.169	30.412	45.54	28.8	6.773	1.572	1.311	0.005	0.127
SFC	12.03	17.51	14.396	31.213	48.5	49.6	6.127	1.437	0.813	0.005	0.073

DRY SEASON

	Protein	Solids	P	Ca	Na	K	Mg	Fe	Zn	Mn	Cu
NBH	14.74	23.13	26.516	29.232	42	75	6.923	1.425	3.3	0.039	0.057
NBH	14.81	22.02	20.115	31.614	28.1	47	6.824	1.58	2.298	0.031	0.149
DJK	17.81	24.42	17.864	29.288	39.9	65	6.851	1.256	6.207	0.022	1.38
DJK	19.81	26.47	13.114	40.557	45	66	6.792	1.369	8.83	0.021	2.5
SNG	12.92	16.99	17.754	29.214	54.7	79	6.872	1.382	3.49	0.005	0.024
SNG	13.87	16.89	30.6	30.517	63.5	64	7.193	1.418	2.01	0.018	0.127
SFC	14.61	20.98	17.37	33.205	53.9	70	6.76	1.689	1.375	0.005	0.032
SFC	13.73	21.42	18.583	30.361	57.6	58.4	7.813	1.631	1.343	0.015	0.131

Appendix 5B

Composition of nutrients in fresh and stored colostrums

	Protein	Solids	P	Ca	Mg	Na	K	Fe	Zn	Mn	Cu
FRESH	11.68	14.32	10.7	40.065	73	89	6.875	1.23	2.06	0.018	0.12
FRESH	13.1	16.23	17.255	33.148	58.5	84	6.443	1.306	1.775	0.014	0.079
STORED	9.31	14.18	14.02	21.3	61	59.3	6.08	0.819	2.18	0.014	0.032
STORED	10.59	14.97	16.03	17.43	66.12	57.22	6.11	1.76	1.67	0.021	0.016

Appendix 6: Estimates of the parameters of the relationship Y = a + bX connecting concentrations of the main constituents and minerals in colostrum

Components (Y/X)	a	slope b	s. e. of b	correlation (14 d.f.) coefficient
Total solids/protein	-0.487	1.450**	0.212	0.971
Total solids/zinc	17.385	1.057*	0.367	0.609
Total solids/copper	19.322	3.098*	1.191	0.571
Calcium/protein	27.485	0.297	0.439	0.178
Protein /magnesium	6.400	1.169	1.463	0.209
Protein/iron	18.810	-3.091	4.253	-0.191
Zinc/protein	-8.317	0.774**	0.149	0.812
Copper/protein	-3.250	0.249**	0.047	0.818
Calcium/total solids	33.418	-8.17^{E}-02	0.269	-0.081
Calcium/phosphorus	37.005	-0.295	0.171	-0.418
Calcium/magnesium	37.005	-0.295	0.171	-0.046
Calcium/iron	40.046	-5.777	7.066	-0.213
Calcium/copper	30.840	2.740*	1.268	0.500
Calcium/manganese	34.712	-0.433	2.495	0.055
Sodium/potassium	14.130	0.468*	0.197	0.537
Phosphorus/magnesium	-11.602	4.305	3.345	0.325
Zinc/iron	10.984	-5.694	3.841	-0.368
Zinc/magnesium	1.809	0.147	1.426	0.028
Zinc/copper	1.857	2.862**	0.339	-0.914
Zinc/calcium	-4.125	0.218	0.141	0.383
Phosphorus/zinc	3.082	-1.51^{E}-02	0.108	-0.038
Magnesium/manganese	6.860	-1.952	8.804	0.059
Sodium/iron	96.656	-37.325*	28.092	-0.335
Potassium/iron	141.863	-55.714	30.784	-0.435

Significance level *P < 0.05; **P < 0.01; s.e. standard error; d. f. degree of freedom.