EVALUATION OF SODIUM BUTYRATE AND CONCENTRATE CRUDE PROTEIN LEVEL ON THE PERFORMANCE OF ARTIFICIALLY REARED BEEF CALVES TO 12 WEEKS

by

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List of Abbreviations

AA	Aberdeen Angus
BW	Body Weight
°C	Degrees Celsius
CMR	Calf Milk Replacer
CP	Crude Protein
DLWG	Daily Live Weight Gain
FCR	Feed Conversion Ratio
IgG	Immunoglobulins
Kg	Kilogram
LW	Live weight
ME	Metabolisable Energy
NDF	Neutral Detergent Fibre
SB	Sodium Butyrate
VFA	Volatile Fatty Acid

Poster

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Evaluation of Sodium Butyrate and concentrate crude protein level on the performance of artificially reared beef calves to 12 weeks.

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Introduction: There has been recent interest in feeding sodium butyrate (SB) to improve the performance of young stock and reducing crude protein (CP) content of concentrates due to increasing price of protein feedstuffs. Therefore it is suitable to investigate these areas to improve efficiency and reduce the cost of calf rearing, which is the most expensive period in beef production (Moran 2002). The objective of this experiment was to investigate the effect of supplementing calf milk replacer (CMR) with SB and concentrates with either 160 or 180g/kg CP on performance of artificially reared dairy breed bull calves to 12 weeks.

Materials and Methods: 24 dairy bred Holstein Continental and 24 Holstein bull calves were allocated using a randomly blocked design to four treatments 12 on each treatment on a 2x2 experiment for 12 weeks. The four treatments were control CMR with either 160 or 180g/kg CP concentrate or SB supplemented CMR with either 160 or 180g/kg CP concentrates. The calves were individually penned from start to weaning, fed 175g of allocated CMR per 825ml of water and fed 1.7litres per feed twice per day at 8:00am and 4:00pm at 37°C. Concentrates allocated were fed *ad lib* with refusals measured weekly up to weaning. The calves were also offered *ad lib* straw and water, with clean bedding applied as and when necessary. They were weaned gradually at 6 weeks on the experiment provided consumption was 1kg of concentrates per day. Calf LW was measured at start, week 1, week 3, week 6 (weaning) and week 12 (finish), along with calf wither height, heart girth, hip height, hip width and last rib girth at the start, week 6 and week 12.

Results: The experiment found that SB supplemented CMR caused a significant increase (P<0.05) in LW at week 1 and DLWG from the start to week 1. Along with the animals having a numerically higher weight and DLWG over 12 weeks. There was no other significant differences in calf performance indicators or intake.

Table 1: The effect of SB supplement on calf performance to 12 weeks.

LW (kg)	Control CMR	SB CMR	s.e.d	P value
Start	54.0	53.8	1.60	0.887
1 week	55.9	57.3	0.52	0.010
3 weeks	66.3	67.3	1.00	0.332
Week 6	82.0	83.4	1.48	0.340
12 weeks	132.8	135.5	4.14	0.523
Increase	78.8	81.7		

Table 2: The effect of SB supplement on DLWG.

DLWG (g/day)	Control CMR	SB CMR	s.e.d	P value
Start-1 week	287	489	74.5	0.010
1-3 weeks	743	713	65.8	0.647
3-6 weeks	922	947	48.0	0.595
Start - Weaning	739	776	38.8	0.340
Weaning - 12 weeks	1128	1161	71.6	0.648
Start - 12 weeks	949	984	50.0	0.488

Conclusion: Average calf performance (regardless of treatment) exceeded the performance figures stated by Dawson *et al.,* (not dated). Therefore the treatments did not limit calf performance. SB supplemented CMR had a significantly increase (P<0.05) LW at week 1 and DLWG from start to week 1 by 1.4kg and 202g/day respectively. CP content of concentrate had no significant effect on performance at any stage thus suggesting no need for 180g/kg CP. No significant effect was seen on concentrate intake or feed conversion. The suggested treatment to rear calves is SB CMR and 160g/kg CP concentrates with the cheapest cost per/kg gain, which can equate to £4/calf over 80kg gain. Current practice of control CMR and 180g/kg CP concentrates had poorest performance start-weaning and most expensive per kg/gain.

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1 Introduction

Successful artificial calf rearing is vital to ensure a high level of productivity and efficiency in beef cattle in the UK and management is key to subsequent health and performance (EBLEX, 2007). However a calf is under the most stress, metabolic, nutritional and behavioural change between birth and weaning. It is the period where financial loss due to mortality is at its highest, hence correct management and nutrition being vital (Davis and Drackley, 1998).

Due to 56% of beef produced being sourced from the UK dairy herd (EBLEX, 2012), artificial calf rearing is a vital component to the UK beef industry due to the dairy cow's milk being used for human consumption. The large number of calves reared artificially tend to be fed with a CMR, and research into this area to maximise performance could have a significant effect within the industry.

Effective rearing of young livestock is determined by a number of factors that can affect the output and performance up to weaning. In relation to calf rearing the factors include: meeting the nutritional requirements in a form suitable for the calf's underdeveloped digestive tract whilst encouraging the development of the rumen to enable the transition of weaning (Garnsworthy, 2005).

The cost of rearing young stock is the most expensive period in livestock production (Moran 2002) and due to fluctuating beef prices farmers need to manage the cost of production and ensure that livestock are grown efficiently as possible. Recent interest in the addition of dietary derived chemicals into young livestock feed has shown that butyrate could have the potential to improve performance and health of young livestock (Kelly *et al.,* 2014).

Interest in diet derived chemicals in particular SB have been investigated with differing results in relation to performance and health in monogastric and ruminant young stock. However it has been concluded to have a beneficial effect on performance but more research is needed to determine economic benefits to calf rearing.

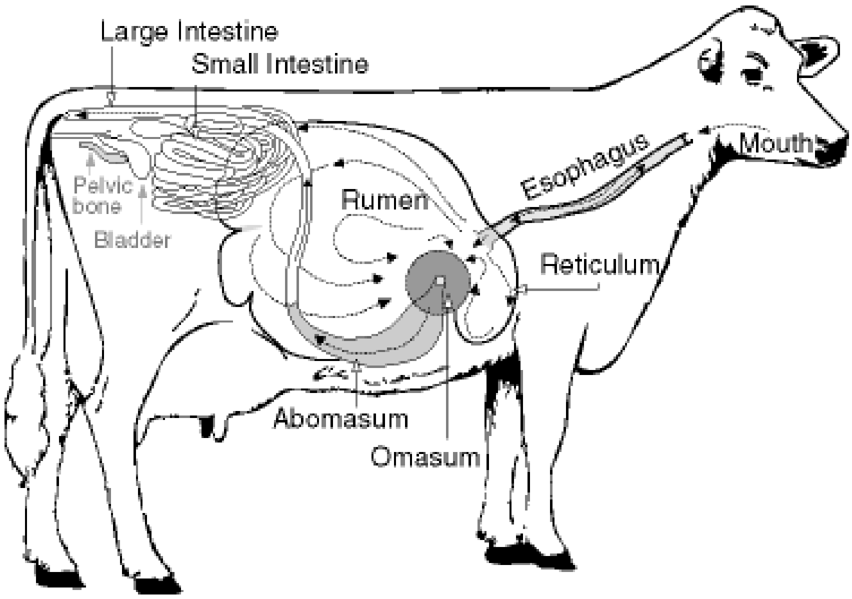
Calves are conventionally reared using 180g/kg CP concentrates. However protein feedstuffs such as soybean meal and rapeseed meal are costing £320/t and £199/t respectively (DairyCo, 2015). Compared to home grown cereal prices of barley and feed wheat being £120/t and £125/t respectively (HGCA, 2015). Thus understanding the optimum protein content of feed and potential reductions can have on farm financial benefits. There has been little recent research challenging the current CMR and concentrate CP practices to ensure UK farmers are applying the best practices.

The objective of this experiment is to evaluate the effect of supplementing dairy bred bull calves with SB and concentrates with either 160 or 180g/kg CP on performance to 12 weeks.

2 Digestive system of the calf

The digestive tract of an adult ruminant is shown in figure 1. However the majority of the digestion is carried out in the animal's stomach compartments. A cattle's stomach consists of four compartments with differing characteristics which is as follows:

- The Rumen: the first and largest compartment where plant cell walls are fermented and broken down by rumen microbes (fungi, bacteria & protozoa), which enables the utilisation of fibrous feed.
- The Reticulum: has a "honeycomb" structure following the rumen which filters digesta, allowing small particles to pass through and ensuring large particles to remain in the rumen for further digestion.
- The Omasum: is a spherical compartment which has many folds within, increasing the surface area enabling the absorption of water and some nutrients.
- The Abomasum: viewed as the "true stomach" which is most like a monogastric stomach. Hydrochloric acid and digestive enzymes breakdown protein and lipids and prepare nutrients for absorption in the intestines.



(Parish, 2011; DairyCo, 2014a)

(Source: Howard and Wattiaux, not dated)

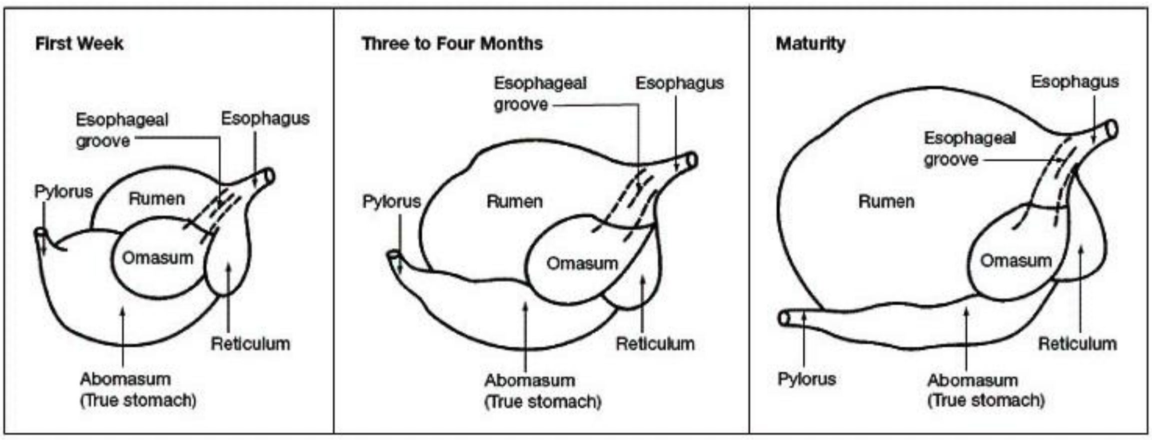
In the first few weeks of age a calf's digestive tract is underdeveloped compared to a mature animal and it is important that the calf is fed the correct feed that can be digested by the calf (Linn *et al.,* 2005). At birth the abomasum is the largest compartment of a calf's stomach making up 50% of the gut capacity (Davis and Drackley, 1998) compared to an adult cow where it makes up only 7% of the gut capacity (Sharipo, 2001). The digestive system changes significantly from the birth with the rumen developing the most.

Figure 1 The Digestive system of a Ruminant

2.1 The Rumen

The rumen in an adult ruminant is the largest of the four compartments to the stomach and follows the esophagus. It is a muscular organ which is lined with “finger like” *papillae* increasing the absorptive area. The feed eaten by the animal enters to rumen to be fermented by a large microbial population and partially absorbed (Sharipo, 2001). Due to the rumen being underdeveloped and non-functional at birth it must undergo papillary growth, muscular growth and vascularisation to meet the future desire to consume forages and dry feed (Heinrichs, 2005).

Heinrichs and Jones (2003) state that the rumen undergoes two stages of development during calf rearing, firstly the physical size of the rumen increases and secondly the elongation of papillae and thickening of the rumen walls. A microbial population is also introduced to a calf’s’ rumen through the environment, bedding and hair. Figure 2 demonstrates the increase in rumen size as the animal develops. Feeding dry feed with rapid fermentation that contain carbohydrates and protein will stimulate its development. This is due to the formation of VFAs from microbial fermentation in the rumen of dry feed. Davis and Drackley (1998) state that early consumption of dry feed is the most important



factor in the development of the calf’s digestive tract.

(Source: Heinrichs and Jones, 2003)

Figure 2 Development of a ruminants stomach.

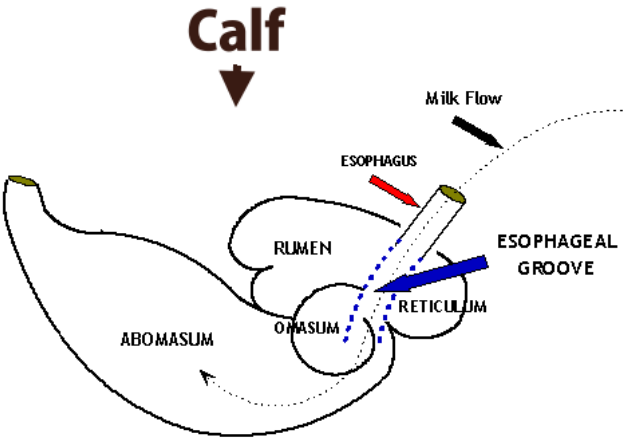
Davis and Drackley (1998) conclude that calves should be consuming feed that is high in grains as opposed to fibre alongside CMR, due to stomach tissue growth and papillae growth responds more to grain consumption. However Coverdale *et al.,* (2004) argues that it is favourable to supply hay alongside grain during the period of liquid feeding because the calves demonstrated increased intake, feed efficiency and higher weights at weaning. Figure 3 illustrates the difference in rumen development when calves are on different diets. Also calves fed large amounts of liquid feed only can0 grow at high rates however the abomasum will be large and the rumen will remain unchanged and underdeveloped which could cause a fall in growth rate post weaning.

(Source: Heinrichs, 2005)

Figure 3 Demonstrates the differing rumen development due to diet.

2.2 The Oesophageal Groove

The oesophageal groove is formed by the folds of the reticulum curling into a tube structure which directs the milk from the lower oesophagus into the omasum and into the abomasum, by-passing the rumen. It is a reflex action that fades over time and does not function post weaning. The milk must by-pass the rumen because if milk enters it becomes fermented and can cause colic, bloat, scour and poor growth. The formation of the oesophageal groove can be stimulated by sound, sight and smell of milk preparation (Garnsworthy, 2005). Figure 4 shows a diagram of the location of the oesophageal groove



(Source: Doel, 2013)

Figure 4 The position of the oesophageal groove in the young ruminant digestive system.

in relation to the stomach compartments.

Choudhary *et al.,* (2010) states that there are a number of factors that can affect the closure of the oesophageal groove, including CMR quality, temperature and milk feeding method and resulting in milk entering the rumen. However, there is a debate on feeding method. Wise *et al.,* (1984) concluded that calves consuming milk via sucking through a teat as opposed to drinking the milk through a bucket had a slower intake of milk which reduced the spillage of milk into the reticulorumen. However Abea *et al.,* (1979) challenges this by concluding that feeding calves with an open bucket compared to teat has no effect on the closure of the oesophageal groove. It is advised to use good feeding practice through a teat as opposed to open bucket (Choudhary *et al.,* 2010).

3 Nutrition of the Calf

Meeting calf nutritional requirements is important to ensure high performance, health status, prevent element deficiencies or toxicities and ensure good rumen development (Sarbacker, 2014). A ration must be able to be consumed by the calf with limited stomach size and at the lowest economic cost. Whilst providing the essential nutrients for a calf which include energy, protein and water with fibre, minerals and vitamins (Moran, 2012).

3.1 Energy

Energy needed to maintain body temperature and bodily functions is known as the maintenance energy requirement, however for growing cattle, additional energy is required for growth of muscle and fat tissue (Moran, 2012). However not all of the gross energy (GE) in feed is available for the calf to be utilised due to losses through faeces, urine, and digestion. The energy available to be used by the calf is defined as Metabolisable energy (ME). Approximately 90% of the GE in CMR is available as ME to the calf compared to forage and concentrates which have 50-60% available as ME. This is partly due to the abomasum being more efficient at digestion compared to the rumen. The calf's diet must meet the ME requirement of the animal however different feed stuff has a differing ME (Moran, 2012).

A calf's ME requirement is dependent on the LW influencing the maintenance requirement of the calf and the target DLWG as shown in table 1.

Table 1 The ME requirement for maintenance and weight gain for milk fed calves at increasing LW.

Body Weight (kg)	ME maintenance (MJ/day)	ME for maintenance + gain/day (MJ/day)				
		M + 227g	M + 340g	M + 454g	M + 567g	M + 680g
45	7.3	9.6	11.1	12.6	14.2	15.9
50	7.9	10.2	11.7	13.3	15.0	16.7
54.5	8.4	10.9	12.4	14.0	15.8	17.6
59	9.2	11.7	13.3	15.1	16.9	18.7
65.9	9.7	12.3	13.9	15.7	17.6	19.5

(Source: Davis and Drackley, 1998)

3.2 Protein

Protein is expressed as CP in feed which is based on the nitrogen content in the feed (Davis and Drackley, 1998). Proteins have an integral part in biological processes, repairing tissue, and muscle growth. When proteins are broken down/hydrolysed by enzymes peptides' ammonia and amino acids are produced. These amino acids are then digested and resynthesized into those required by the calf for maintenance and growth (Moran, 2002). The efficient use of proteins is dependant on the proteins and amino acids supplied in the feed (Charlton, 2009). Table 2 shows the CP requirement of a calf.

Table 2 CP requirement of the neonatal calf.

	Maintenance plus DLWG (kg/day)			
LW	0.45	0.68	0.91	1.0
(kg)	(g/day)			
60	224	269	372	399
70	229	301	373	402
80	237	305	377	405
90	241	308	379	406
100	243	313	384	410

(Source: Davis and Drackley, 1998)

CP supplied in feed has two constituents, rumen degradable protein (RDP) and un-degradable dietary protein (UDP). RDP is the non-protein nitrogen broken down by rumen microbes into peptides and ammonia which is resynthesized into microbial protein. The rate of the synthesis is based on the energy metabolism of rumen microbes. Up to 80% of microbial protein can be digested by the host thus making microbial protein very digestible (McGill University, not dated). The organisms are then digested in the abomasum and small intestine of the host. The key importance of microbial protein is that it contains amino acids that cannot be synthesised by the host despite not being supplied in the diet, as well as utilising non protein nitrogen compounds into microbial protein. This enables compounds such as urea to be added to the diet (McDonald *et al.,* 2010). Pathak (2008) discussed factors affecting microbial synthesis as follows:

- Fermentable energy supply is the first limiting factor for microbial growth. If energy supply is limited, the growth and population of the microbes is reduced and protein synthesis is restricted.
- A higher dry matter intake influences the microbial population and growth thus increasing microbial protein synthesis.
- The amount of RDP supplied will affect microbial protein synthesis by determining how much protein the microbes can use, the RDP proportion differs in feed stuffs.
- A low pH in the rumen reduces the ability of the microbes to function and synthesis of microbial protein.

These points highlight that the supply of RDP is not the only limiting factor for the synthesis of microbial protein.

However if there is a large amount of RDP and low energy then the excess RDP will turn into ammonia. This is then absorbed through the rumen wall and converted into urea in the liver, and lost through urine, causing loss off protein. UDP is desirable to be fed to young calves due to the undeveloped rumen and milk directly entering the abomasum. Figure 5 shows the passage of CP when consumed by a ruminant.

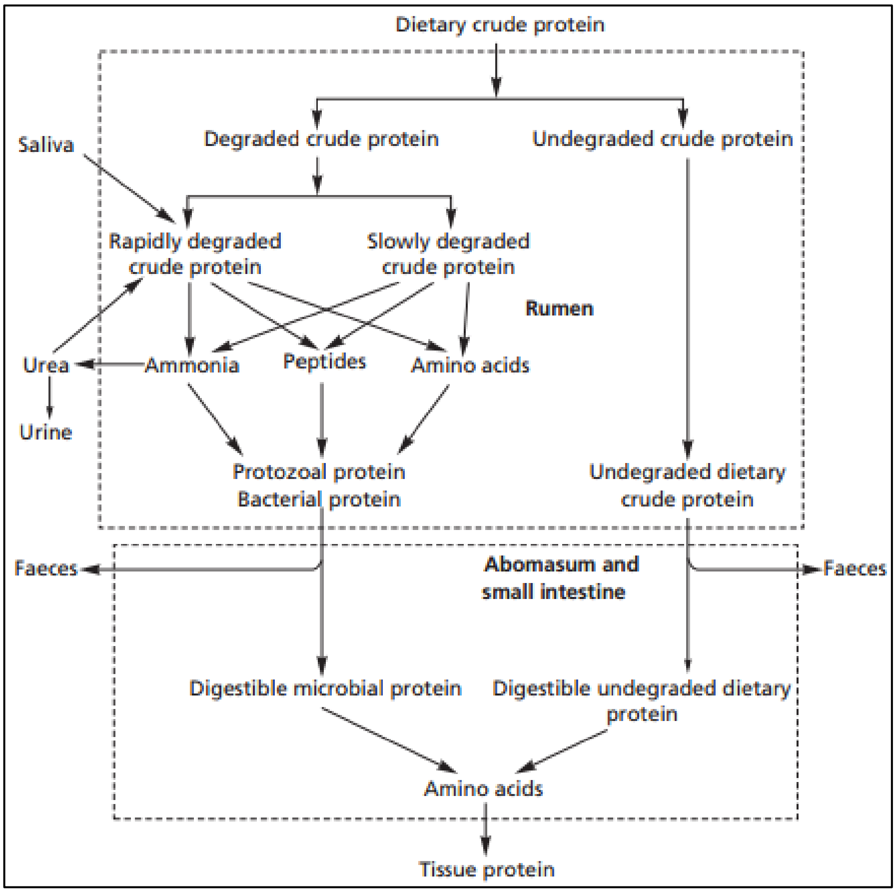


Figure 5 Passage of crude protein in a ruminant.

(Source: McDonald *et al.,* 2010)

3.3 Water

Water vital to a calf by supporting a number of bodily functions, including metabolic reactions, nutrient transportation, maintaining body temperature and is the major component in animal cells (Field and Taylor, 2008). Table 3 shows required water intake of calves at increasing ages, and highlights that a calf at 1 month of age requires over 5litres of water from sources excluding liquid feed.

Table 3 The water requirement for calves of increasing ages.

Age (months)	Requirement (litres/day)
1	5 - 7.5
2	5.5 - 7.5
3	8 – 10
4	11 - 13.5

(Source: Charlton, 2009)

Water is also needed by the rumen microbes to ferment dry feed, hence dry feed intake is stimulated by water availability and consumption (Charlton, 2009). Water is also important for the hydrolysis of fats, proteins and carbohydrates along with aiding the absorption of nutrients. Therefore providing additional water other than what is consumed with other feed i.e. CMR is important (Heinrichs and Jones, 2003). Kertz *et al.,* (1984) emphasise these statements by concluding that weight gain of calves with deprived water access was below the median and the intake of these calves was reduced compared to calves with ad lib water availability.

3.4 Minerals and Vitamins

Vitamins and minerals are only needed in small amounts compared to other nutrients. However they are still very important to sustain the life, growth and development of the calf and aid the immune response (Charlton, 2009).

Vitamins are classed as fat soluble which include vitamin A, D, E, and K or water soluble vitamins which include B and C vitamins. Vitamin A influences growth, reproduction and immune response by regulating cellular differentiation, formation and protection of epithelial tissues and promotes healing. Deficiency symptoms include night blindness, low appetite, and low growth (McDonald *et al.,* 2002). Vitamin D is responsible for the absorption and metabolic use of phosphorous and calcium from the digestive tract. The role of Vitamin E is an antioxidant to prevent the destruction of other vitamins and fatty acids in the digestive tract (Sewell, 1993). Reddy (1987) concluded that supplementation of vitamin E in doses of 125 or 250µg/day led to significantly higher weight gains and increased feed efficiency in comparison to calves supplemented with 0µg/day. B vitamins are involved as co-factors in enzyme systems that are involved in the metabolism of energy and protein. However there is no need to supplement a pre-weaned calf's diet due to adequate amount synthesised in the recto-rumen (Davis and Drackley, 1998).

Minerals are classed as major or minor based on the amounts required by the animal (Hale and Olson, 2001). Table 4 highlights minerals required by a calf and the role each mineral plays in the body.

Table 4 Minerals required by a calf and its role.

Major Mineral	**Role**
Calcium	Formation and maintenance of bone and teeth, and for nerve impulses of muscles.
Phosphorus	Formation of bone and for energy metabolism.
Potassium	Role in osmotic regulation of bodily fluids, acid balance in the animal and nerve and muscle excitability.
Sodium	Role in osmotic regulation of bodily fluids, acid balance in the animal and is a cation of blood plasma.
Chlorine	Role in osmotic regulation of bodily fluids, acid balance in the animal and is part of gastric secretion as hydrochloric acid and salts.
Sulphur	Synthesis of rumen cysteine, cysteine and methionine.
Magnesium	Activator for metabolic enzymes of which control a range of reactions including replication of DNA.
Trace Mineral	
Iron	Part of a number of biochemical reactions.
Copper	Haemoglobin synthesis.
Cobalt	To enable the synthesis of vitamin B12 by rumen bacteria.
Iodine	Essential for the production of the hormone thyroxin which regulates metabolic rate.
Manganese	Activator in several enzyme systems such as hydrolysis.
Zinc	Activator in several enzyme systems such as cell replication.

(Source: McDonald *et al.,* 2002 : Hale and Olson, 2001)

Heinrichs and Jones (2003) suggest that CMR and starter concentrates fed to calves provide adequate minerals and vitamins to meet the demand in the first few weeks of life and therefore mineral and vitamin supplementation should not be required.

3.5 Colostrum

Colostrum has three main components including, Immune factors (Immunoglobulin), growth factors and nutritional components which cannot be passed through the placenta. It is the initial secretion from the mammary gland post parturition to be supplied to the new-born calf. This ensuring the new-born calf consumes early and an adequate volume of high quality colostrum with high IgG content is a vital factor affecting calf survival and heath in the first few weeks of life (Davis and Drackley, 1998). This point is reiterated by Wells *et al.,* (1996) concluded that the majority of dairy heifer mortality boasted 31% of death within the initial 21 days and could have been by prevented altering the method, timing and volume of the initial colostrum feed. The timing of colostrum intake is important due to colostrum quality and the calf's ability to absorb IgG via passive transfer decreases over time with little absorption taking place 18-24 hours after birth. Therefore The Welfare of Farmed Animal (England) Regulations 2000 states that calves must receive bovine colostrum in the first 6 hours of life (Ohnstad, 2015). It is stated by DairyCo (not dated) that calves should consume 10% of its body weight in the first 24 hours of life and 5% in the first 6 hours.

Colostrum also contains growth factors such as insulin-like growth factor 1 and 2 and epithelial growth factor, which are important for initial gut growth and development in the calf (Pakkanen and Aalto, 1997).

Colostrum has a higher energy and nutritional value compared to standard milk, this enables the calf to consume high energy feed to maintain body temperature and movement once the limited energy reserve has been used. Table 5 quantifies the difference between colostrum and milk, it also compares the difference in colostrum quality over time after parturition (Davis and Drackley, 1998).

Table 5 Comparison between colostrum over time after parturition and milk.

	Timings after parturition			
Component	1	2	3	Milk
Solids (%)	23.9	17.9	14.1	12.9
Fat (%)	6.7	5.4	3.9	4.0
Protein (%)	14.0	8.4	5.1	3.1
IG (g/100ml)	3.2	2.5	1.5	0.06
Minerals (%)	1.11	0.95	0.87	0.74
Vitamin A (µg/100ml)	295	190	113	34

(Source: Foley and Otterby, 1978)

4 Feeding systems and Performance targets

The liquid feeding period is the most expensive per unit of feed during the animals' life and selection of which method used should be based on how suitable the method fits in relation to:

- The housing and facilities available on farm.
- Services available i.e. water, milk.
- Number of calves to be reared.
- Labour availability and level of stockmanship
- Performance target during the liquid feeding period (Charlton, 2009).

4.1 Milk, Concentrates and Forage

Calves are fed either milk or CMR when reared artificially because of the undeveloped digestive tract and inability to digest solid feed at a young age as explained in chapter 2. Milk is the most natural feed for young calves which is high in energy and meets the initial protein, mineral and vitamin demands, and calves fed whole milk scour less compared to those on CMR (Moran, 2002). However Charlton (2009) suggests whole milk is deficient in some vitamins and mineral such as Iron and Magnesium. A CMR is formulated to be a substitute for natural whole milk using by-products from the dairy industry, which are able to be used on farms that do not have access to whole milk (DairyCo, 2008). CMR often have added vitamins and minerals to meet the demands of a growing calf (Leggate, 1996a). Table 6 shows the typical chemical composition of a CMR.

Table 6 Typical CMR composition.

Nutrient	Amount
Crude Protein	20-26%
Fat/Oil	16-20%
Ash	<9%
Fibre	<1%

(Source: Volac, 2012)

There are two types of CMR, whey or skim based. Skim based CMR contains 50-60% dried skimmed milk powder from the butter industry whereas whey based CMR are made up of whey from the cheese industry and whey based concentrates (Anon, 2015). As a result skim based CMR clots in the abomasum, slowing the release and reducing the risk of digestive upset and scour (Leadley and Sojda, 2004). Marsh (2010) found there was no significant difference in performance of calves fed either whey or skim based CMR therefore suggesting there is no difference in performance between the two CMRs.

Hill *et al.,* (2008a) measured performance of dairy bred calves on differing liquid feed programs. Treatment A was 100% CMR, treatment B 50% CMR and 50% whole milk and treatment C was 100% whole milk. DLWG in treatment A was significantly higher (P=0.05) and feed efficiency was significantly higher (P<0.05) compared to calves on treatments B and C. No difference in faecal scores and days with abnormal faeces on the different treatments which therefore challenges Moran (2002).

Work has been done to determine the optimum CMR to be fed to calves. Terre *et al.,* (2006) found that calves fed 180g/l of CMR had numerically higher DLWG and LW compared to calves fed 125g/l. However the feed conversions were the same resulting in the cost of LW gain to be more expensive. Marsh (2013) also found feeding 750g of CMR compared to 500g had numerically higher 12 week weights (2.5kg) and had significantly higher (P<0.05) DLWG in the first 3 weeks, but the cost per kg of gain was 10p higher. Hence DairyCo (2014b) suggests that calves should be fed twice per day using 625-

750g/day (125g/l) of CMR. A calf would consume 25-30kg of CMR if weaned at 6 weeks old and is a significant calf rearing cost.

Early consumption of dry feed is a major factor in calf rearing due to the importance of dry feed stimulating rumen development as discussed in chapter 2, and therefore enabling the transition from liquid feed to dry feed at weaning and should be offered *ad lib* (Davis and Drackley, 1998). Heinrichs and Jones (2003) demonstrate the importance of concentrate

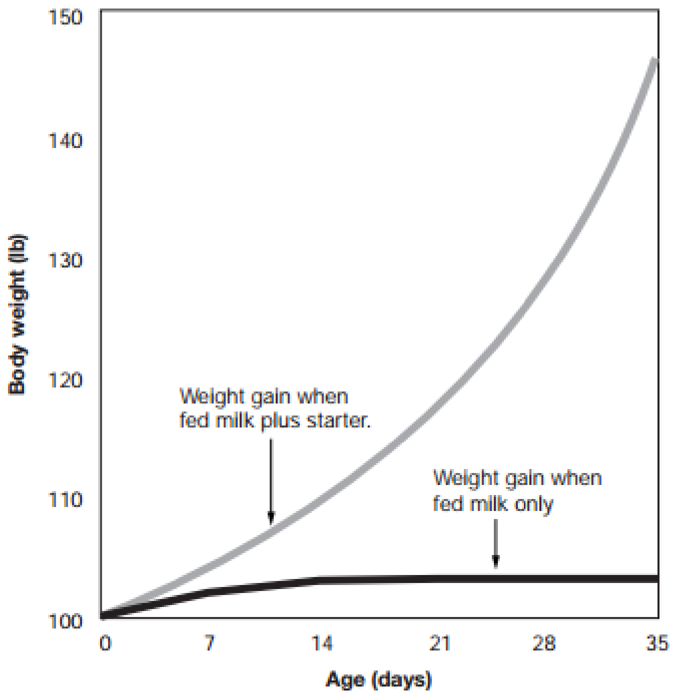


Figure 6 Relationship between starter intake and weight gain and effect on calf weight.

intake due to its effect on weight gain as shown in figure 7.

(Source: Davis and Drackley, 1998)

Calf concentrates can be supplied in the form of a pellet or a coarse mix and should not be very fine or dusty due to the inability to stimulate rumen development and is less palatable (Charlton, 2009). Marsh (2008a) found calves fed concentrates in pellet form had significantly higher ($P<0.05$) DLWG in the first 21 days and post weaning (6 weeks) to 12 weeks of age compared to those fed a coarse concentrate. However Porter *et al.,* (2007) conclude the opposite to Marsh (2008a) by stating that calves had a significantly higher ($P<0.05$) DLWG when fed a coarse mash concentrate compared to pellet form.

The consumption of fibrous forage is beneficial to a calf by encouraging the development of the rumen (Dawson *et al.,* not dated) by increasing the muscular depth its wall and maintaining the health of the epithelial tissue. However intake of straw or hay should be limited due to forages being a less energy dense feed compared to concentrates (Heinrichs and Jones, 2003). Castells *et al.,* (2012) concluded that providing forage in particular barley straw significantly increased ($P<0.001$) the DLWG of calves over the trial period up to 71 days old, and the starter concentrate intake compared to calves not offered any form of forage. Thus reiterating the benefit of feeding forages to calves. Although Khan *et al.,* (2011) found that calves fed a high level of milk and the consumption of forage had little effect on the DLWG and body weight of the calves but the intakes were higher however not significant although reticulorumen weight was significantly higher.

4.2 Restricted Milk feeding systems

Restricted feeding systems is where calves are fed limited amount of milk or CMR each day, often carried out by feeding calves once or twice per day. The restriction of milk aims to encourage early and high consumption of concentrates which are less expensive compared to milk or CMR (Charlton, 2009). Twice per day feeding is the most common method in the UK and it typically comprises of feeding 2litres of CMR which contains 100g/l of replacer, twice every 24 hours at similar times each day. In comparison once per day feeding comprises of feeding 2.5-3l of replacer per day containing 200g/l of replacer and fed once per 24 hours at the same time each day (Harper and Webster, 2008).

Marsh (2011) found that calves fed once per day gained an additional 3.6kg from start to 12 weeks compared to calves fed twice per day, however the additional weight gain was not statistically significant. Marsh (2007) also found that calves fed twice per day had significantly higher DLWG from the start (5 days old) to the first 3 weeks during the experiment. Stanley *et al.,* (2002) however found a very small difference of only 0.4kg over the trial period. However DEFRA (2013) now state that calves under the age of 28 days must be fed milk or CMR twice per day.

4.3 Ad libitum milk feeding systems

Ad libitum (*ad lib*) milk feeding programs for calves offers the calf 24 hour access to milk allowing the calf to consume as much milk as it desires on its own accord. *Ad lib* milk or CMR can be supplied cold from a teat container or warm via a machine (DairyCo, not dated). Leggate (1996b) comments from a practical point of view that consumption of milk/CMR can reach 7-10 litres per calf per day and a DLWG of 1kg, however a higher amount of straw bedding is used and concentrate intake is low. Jasper and Weary (2002) however only achieved 0.78kg/day of LW. Huuskonen and Khalili, (2008) also found that calves only grew 0.69kg/day during ad lib milk feeding on experiments. This suggests that weight gain achievable on *ad lib* systems is variable.

Jasper and Weary (2002) found that *ad lib* milk feeding increases LW gain (0.78kg/day) during the feeding period compared to conventional twice per day feeding (0.48kg/day). Huuskonen and Khalili, (2008) agree with this based on a similar experiment. The two trial emerged with differing conclusions with Jasper and Weary (2002) concluding that *ad lib* allows for increased milk intake and weight gain with no detrimental effects on solid food intake post weaning. However, Huuskonen and Khalili (2008) conclude that *ad lib* milk feeding increased variation in CMR consumption and weight gain compared to conventional twice per day restricted feeding.

4.4 Performance targets

The performance of calves is influenced by a number of factors such as genetics, feeding regimes, housing and health, thus targets should be based on management factors and aim to minimise health issues (Harper and Webster, 2004).

Understanding and measuring performance is important to plan feeding strategies, detect any health issues in poor performance calves and ensure growth is economically viable. The performance of calves can be assessed by measuring the calf's weight, hip width, and height, wither height, heart girth and rumen girth. The performance of calves is primarily influenced by feeding management and health management, and is secondarily influenced by breed, genetics and sex (Charlton, 2009). Table 7 shows targets for different milk feeding systems and demonstrates that feeding systems influence the performance of calves.

Table 7: DLWG Gain Targets on differing milk/CMR feeding systems.

Feed Management	0-5 weeks age DLWG (kg)	0-12 weeks age DLWG (kg)
Once/day feeding	0.4	0.7
Twice/day feeding	0.5	0.7
Cold *ad lib*	0.7	0.8
Machine *ad lib*	0.8	0.8
Accelerated/enhanced	0.8+	0.9+

(Source: Charlton, 2009)

The birth weight of calves can also influence the performance of calves and there LW at weaning and 12 weeks, and that a target weight for Holstein bulls at 12 weeks is 100-125kg (Harper and Webster, 2008). Figure 6 shows the effect on DLWG of differing start weights of Holstein bull calves.

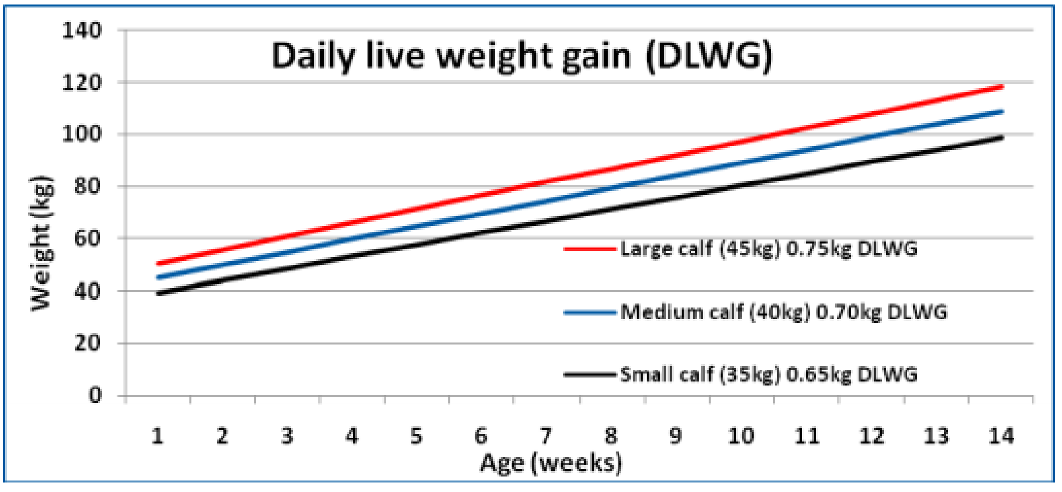


Figure 7 Graph shows DLWG of calves at different start weights.

(Source: Harper and Webster, 2004)

The target DLWG and weights for dairy breed bull calves is shown in table 8 with slight variations within breeds.

Table 8 Target DLWG and weights during the calf rearing period for differing breeds.

Weight	Holstein X Friesian (kg)	Hereford/AA	Continental (kg)	DLWG
1 week	48	45	50	
6 weeks	73	70	75	0.7
12 weeks	102	100	105	0.7
15 weeks	119	117	122	0.8

(Source: Dawson *et al.*, not dated)

4.5 Weaning strategies

Charlton (2009) describes the weaning of a calf as the process of transferring calves from a liquid based diet onto a solid feed diet. Calves can be weaned abruptly or gradual, and should be based on:

- Starter concentrate consumption, suggested 1kg/day (DairyCo, 2008).
- Stress levels.
- Healthy and growing.
- Sufficient rumen development.

Gradual calf weaning comprises of gradual reduction of liquid feed overtime prior to weaning and is the preferred method, compared to abrupt weaning which is when liquid feed is fed at the full rate then removed completely at weaning (Charlton, 2009).

Sweeny *et al.,* (2010) measured the performance of calves weaned abruptly compared to calves weaned gradually over 4, 10 and 22 days. Calves weaned abruptly experienced weight loss 8 days post weaning and calves weaned over 10 days gradually recorded the highest weight gains. Similarly Marsh (2008b) found weaning gradually over 5 days had significantly higher DLWG ($P<0.05$) from weaning to 11 weeks, which resulted in an extra 8.6kg and lower feed cost. Both studies highlight benefits to gradual weaning which is suggested by Charlton (2009).

Fiemsa *et al.,* (2005) measured performance of calves weaned when consuming 0.5, 0.75 or 1.0kg/day of concentrates. The calves weaned when consuming 1.0kg/day had significantly higher ($P<0.05$) DLWG pre and post weaning thus concluding calves should be weaned when consuming over 0.75kg/day. Marsh (2006) supports this view as calves weaned when consuming 1.25kg/day as opposed to 0.75kg/day had a very highly significant DLWG from weaning to 12 weeks, with the calves being 4.3kg heaver at 12 weeks however cost of LW gain was slightly higher. Therefore weaning is suggested when consuming 1kg/day to reduce the cost of LW gain.

The weaning age of calves studied by Hopkins (1997) found calves weaned at 8 weeks had higher DLWG however the difference was not significant compared to 4 weeks old. This was then taken further by Kehoe *et al.,* (2007) who also found that there is no significant difference in the weight of calves at 8 weeks old when weaned at 3, 4, 5, or 6 weeks. However the daily weight gain of the calves increased as weaning age increased but was also not significant. The studies therefore suggest that weaning should be done gradually when consuming 1kg of concentrates as opposed to age as stated by Charlton (2009).

5 Review of protein levels of concentrates for calves

Protein is a very important nutrient to a growing calf as explained in chapter 3.2 for health and growth. Protein is supplied to the calf from primarily starter concentrates with CMR containing some protein, Table 9 suggests the nutrient requirement of a calf starter.

Table 9 Recommended calf starter nutrient composition.

Nutrient	Amount
Energy (ME)	13.8MJ/kg
Protein	18-20%
Fat	3-5%
NDF	12-25%
ADF	6-20%
DUP	0.65%

(Source: Charlton, 2009)

A number of studies have investigated CP content in concentrates including Akayezu *et al.,* (1994) who studied calf growth between 4-56days with starter feeds of 140, 165, 190 and 225g/kg CP. Calves on 190g/kg CP recorded the highest DWLG of 0.62kg/day and increased linearly as CP increased ($P<0.01$). However calves fed the 22.5% starter had lower DLWG when compared to 190g/kg CP. Intake also increased linearly ($P=0.02$) as CP content increased but feed efficiency was similar with all treatments. Akayezu *et al.,* (1994) concluded that the NRCC recommended 180g/kg CP calf starter feed is the optimum for growth and performance and higher offers no advantages. Also adequate performance was recorded with those calves on lower CP diet and therefore diets should be altered in accordance to economic return.

Hill *et al.,* (2007) also studied differing CP contents of calf starter feed over several experiments form 0-56days, one trial compared CP contents of 180, 200, 220, 240, and 260g/kg CP and found that calves fed 180g/kg had a higher DLWG of 0.681kg/day compared to calves on other amounts. However those fed 260g/kg CP recorded a marginal higher DLWG of 0.688kg/day and hence concludes that there is no benefit to feeding a starter with more than 180g/kg CP which agrees with Akayezu *et al.,* (1994). An alternate trial measured starter concentrates with 150, 180 and 210g/kg CP. Calves fed 180g/kg CP feed had highest DLWG and a quadratic increase occurred ($P=0.05$), with calves on 210g/kg having lower DLWG.

A later study by Hill *et al.,* (2008b) measured the performance of weaned calves on differing CP diets. Trial 1 compared 160 and 180g/kg CP feed based on soybean meal. No difference in DLWG, feed efficiency, and intake was found. A different trial had feed with 135, 150, 165 and 180g/kg CP found that calf DLWG and feed efficiency showed an increasing quadratic response with 165g/kg CP having marginal higher DLWG compared to 150 g/kg CP feed. Hill *et al.,* (2008b) conclude that weaned calves should be fed a diet with CP content of 150g/kg, and suggests that CP should decrease as the calf grows and develops.

Protein feedstuffs such as soybean and rapeseed meal are £320/t and £199/t respectively (DairyCo, 2015) compared to cereal prices of barley and feed wheat being £120/t and £125/t respectively. It is therefore appropriate to carry out an experiment to determine economic viability of feeding 180g/kg CP concentrates or whether a reduction in CP is more cost effective.

6 Review of feeding Sodium Butyrate to calves

The interest in diet derived chemicals to enhance the gastrointestinal health, immune response and the growth of young calves is increasing and butyrate has been found to have potential in these desired areas (Kelly *et al.,* 2014). SB is a sodium salt of butyric acid (Na-butyrate) that increases the stability and reduces the odour of the acid enabling it to be added to animal feed stuffs (Guilloteau *et al.,* 2009).

Butyric acid is a VFA that is naturally occurring substance present in the rumen due to microbial fermentation and break down of carbohydrates. It is also present in cow's milk at a rate of 0.16g/l (Guilloteau *et al.,* 2009). Butyric acid makes up 12-18% of the total VFA's in the rumen and supplies energy to the rumen wall, milk fat synthesis and body fat synthesis (Ishler and Heinrichs, 1996). It also stimulates epithelial cell proliferation, regulates cell differentiations, apoptosis of the gut and is the preferred energy source for the colon and rumen epithelial cells. Butyric acid has anti-inflammatory, cytoprotective and antibacterial properties aiding the immune system of the animal (Gorka *et al.,* 2009).

Guilloleau *et al.,* (2010) states that butyrate operates in a number of ways within the body as shown in figure 2. It is a signal for regulating the balance of proliferation, differentiation and apoptosis of cells in homeostasis of colonocytes. Butyrate is also the main source of energy for colonocytes and therefore an increase in energy will stimulate an increase in cell growth. Butyrate also enhances these processes by influencing gene expression and protein synthesis. Gastrointestinal is stimulated to release peptides and growth factors which act on cell proliferation.

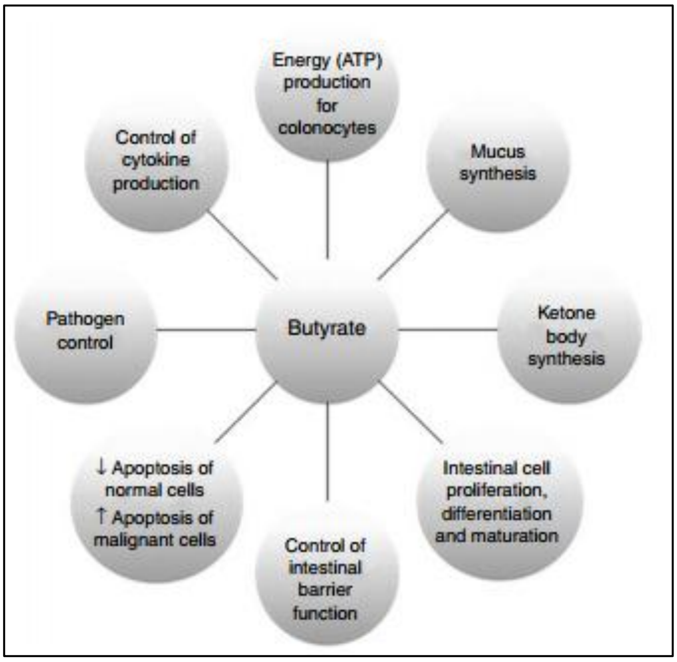


Figure 8 The local effects of butyrate when in the intestine.

(Source: Guilloteau *et al.,* 2010)

Work carried out by Fang *et al.,* (2014) who conducted a 21 day trial on piglets aged 28 days on supplementing feed with SB found that final weight, DLWG, and feed conversion were numerically higher in piglets supplemented with SB however not significantly higher. Weber and Kerr (2008) also found that supplementing feed with SB can increase the LW and DLWG of piglets post 28 days. In comparison Tonela *et al.,* (2010) used piglets from 21 days old over 5 weeks, found that there was no difference in LW when supplemented with butyrate and no difference which different salts. However empty weight and length of the piglets' large intestine was significantly reduced (P<0.05) when butyrate was included. However Fang *et al.,* (2014) results are more reliable because 100 piglets were used, which was considerably higher than Tonela *et al.,* (2010).

In poultry Hu and Guo (2007) found that body weight gain increased linearly significantly (P<0.05) when increasing amounts of SB were supplemented in the diet from 0-21days. Also the ratio of villos height to crypt depth increased which is a beneficial ratio for digestive tract maintenance.

Work carried out by Guilloteau *et al.,* (2009) initially compared the performance of calves supplemented with SB compared to Flavomycin in CMR and starter concentrates. The DLWG and feed efficiency of calves over the whole trial was significantly higher (P=0.02) when supplemented with SB compared to Flavomycin. There was no significant difference in DLWG during the milk feeding period however calves supplemented with SB compared to Flavomycin had higher DLWG (0.644kg/d v 0.608kg/d respectively). However there was no control containing no supplementation in this experiment and therefore the benefit of SB compared to standard feed is not known.

Gorka *et al.,* (2009) studied the effect of SB supplementation on calf performance over a 3 week period, DLWG was not significant and mean weight gain was higher when supplemented with SB but not significant (2kg v 0.3kg). However the weight gain and DLWG was less than observed by Guilloteau *et al.,* (2009) and below the target performance mentioned in chapter 4.4, only 14 calves were used on the trial. Gorka *et al.,*

(2009) concluded that SB may enhance rumen development suggesting more research is needed. A later experiment by Gorka *et al.,* (2011) compared the method of SB inclusion i.e. in CMR or starter feed. Calves fed SB supplementation in CMR had significantly higher weights at day 7, 14, and 21 ($P<0.05$). However supplementation in starter feed had no difference. It was concluded that SB supplementation in CMR has positive effect on performance and health.

Recently Kelly *et al.,* (2014) found that calves supplemented with SB increased pre-weaning DLWG ($P=0.08$) of 0.69kg/d compared to the control of 0.59kg/d. this growth rate is similar to that seen by Guilloteau *et al.,* (2009). No difference in intake was noted however feed efficiency was improved by SB supplementation ($P=0.08$). Kelly *et al.,* (2014) found that papillae length and width was not affected similar to Guilloteau *et al.,* (2009) which found that intestinal length was not affected. Kelly *et al.,* (2014) then concluded that SB could improve pre weaning weight/performance of dairy calves suggesting that more work is required.

These reports are relevant to the area the experiment investigates however none are the same as the following experiment that was proposed.

7 Materials and Methods

Aim

The objective of this experiment was to investigate the effect of supplementing calves with SB and concentrates with either 160g/kg or 180g/kg CP on performance of artificially reared dairy breed bull calves to 12 weeks.

Experimental Material

The trial was carried out from October 2014 to February 2015 in the Beef Unit at Harper Adams University using 48 bull calves, 24 Continental cross Holstein and 24 Holstein which were sourced from the Harper Adams Dairy unit and local high health status dairy herds. The Shine CMR and concentrates were supplied by Bonanza Calf Nutrition who sponsored the trial.

Treatments

The trial had four treatments based on a 2x2 factorial design with 12 calves per treatment, calves were allocated using a randomly blocked design based on LW and breed. The treatments were:

1. Control CMR and 160g/kg CP concentrate.
2. Control CMR and 180g/kg CP concentrate.
3. SB supplemented CMR and 160g/kg CP concentrate.
4. SB supplemented CMR and 180g/kg CP concentrate.

The SB supplemented CMR contained 15kg/tonne of SB.

Management

The calves were individually penned from start to weaning and fed 175g of Shine (a skim based CMR) per 825ml of water and fed 1.7l per feed twice per day at 8:00am and 4:00pm at 37°C, i.e. each calf consumed 600g of CMR per day. The calves were fed *ad lib* concentrates based on treatment with using a known measure recorded and refusals were measured weekly up to weaning. Calves were also offered *ad* lib straw in racks and water with clean bedding applied as and when necessary. The calves were weaned at 6 weeks on the experiment provided consumption was 1kg of concentrates per day then 3 days prior weaning calves were reduced to half rate CMR for gradual weaning. The calves were then moved into group pens for each treatment fed *ad* lib concentrates according to treatment and recorded to calculate group intakes, *ad* lib straw and water was also offered. The calves were disbudded at 3 weeks on experiment, electrolyte mixtures were feed to those with scour issues and the temperature of any calves seen unwell and then the university treatment protocol was adhered to.

Measurements

Calf LW was measured at start of the trial, week 1, week 3, week 6 (weaning) and week 12 (finish) to one decimal place, along with calf wither height, heart girth, hip height, hip width and last rib girth were measured at the start, week 6 (weaning) and week 12 (finish) to the nearest cm. The measurements were carried out by the same person and at the same of the day (after feed) to ensure measuring consistency and rumen fill and weights were equal.

Null Hypothesis

The null hypothesis for the experiment are as followed:

- There is no difference in calf performance when CMR is supplemented with SB.
- There is no difference in the performance of calves fed 160 or 180 g/kg CP concentrates.
- There is no difference in calf performance when fed SB and concentrate CP levels of 160 or 180 g/kg.

Replicates

The replicates were based on the Standard Errors of Difference from previous trials hence 48 calves where used to allow any significant differences to occur.

Statistical Analysis

The results were then analysed to determine any significant differences using Gentsat 13th edition using ANOVA (analysis of variance).

7.1 Chemical Analysis of the CMR and Concentrates

The feedstuffs used in the experiment were chemically analysed independently by Rumenco to ensure the feedstuffs to check the chemical analysis stated by the manufacture of the feed matches the chemical analysis of the feedstuffs. Samples were analysed and demonstrated in tables 10, 11 and 12. The feedstuff in the concentrates is shown in appendix 1.

Table 10 Chemical analysis of the control and Sodium Butyrate supplemented CMR from the manufacture and Rumenco.

	Control CMR		SB supplemented CMR	
Source of Analysis	Statutory Statement	Rumenco Analysis	Statutory Statement	Rumenco Analysis
Chemical component (as fed)				
Dry Matter (%)	96.0	98.3	96.0	98.3
Crude Protein (%)	20.0	20.4	20.0	19.9
Ash (%)	7.5	11.2	7.5	6.1
Fibre (%)	0.07	0	0.07	1.0
Oil (%)	17	12.7	17	18.1

(Source: Authors Own, 2015)

Table 11 Chemical analysis of the 160g/kg CP concentrates from the manufacture and Rumenco.

	160g/kg CP Concentrates		
Source of Analysis	Statutory Statement	Rumenco Analysis 1	Rumenco Analysis 2
Component (as fed)			
Dry Matter (%)		89.0	88.8
Crude Protein (%)	16.0	16.3	16.2
Oil B (%)	4.6	7.3	7.9
Fibre (%)	10.3	9.4	8.4
Ash (%)	9.0	8.2	7.2
Starch (%)	18.5	28.8	30.0
Sugar (%)	6.7	14.0	11.3
NDF (%)	28.0	27.6	26.9
ME (MJ/kg DM)	12.6	13.2	13.5

(Source: Authors Own, 2015)

Table 12 Chemical analysis of the 180g/kg CP concentrates from the manufacture and Rumenco.

	180g/kg CP Concentrates		
Source of Analysis	Statutory Statement	Rumenco Analysis 1	Rumenco Analysis 2
Component (as fed)			
Dry Matter (%)		86.4	86.4
Crude Protein (%)	18.0	18.2	17.8
Oil B (%)	4.9	9.1	9.7
Fibre (%)	9.8	9.1	9.2
Ash (%)	9.0	7.0	6.6
Starch (%)	18.5	26.1	26.4
Sugar (%)	5.7	8.6	8.9
NDF (%)	28.1	32.8	33.8
ME (MJ/kg DM)	12.6	13.0	13.0

(Source: Authors Own, 2015)

The concentrate CP levels are similar to those stated by the manufacture therefore the trial studied the stated CP levels in concentrates. However the oil, starch, sugar fractions and ME were higher than stated for the concentrates. The CMR had the same CP content as stated therefore there is no difference in protein supplied by the CMR, and the only change is in the concentrates. Other chemical aspects in the CMR and concentrates differ slightly from stated but would not influence the trials.

8 Results

The data collected from the experiment was analysed using Genstat 16th edition using ANOVA. The results are shown in the following tables, comparing the performance between calves fed control or SB supplemented CMR regardless of concentrate CP, comparison between 160g/kg and 180g/kg CP concentrate regardless of CMR, and the comparison of the interaction of each treatment. The means, standard error of difference (s.e.d), probability (P value) and any level of significance is shown in the tables. Two calves died during the experiment and there results were excluded from the analysis. Breed and start weight were taken into account when doing the analysis and had numerous effects shown in appendix 2.

8.1 Age

There was no significant difference in start age on the treatments (P>0.05) as shown in tables 13, 14 and 15, but there was a slight trend that calves on 160g/kg CP were numerically older. Overall start age had no effect on the trial and that any effects are due to the treatments.

Table 13 Average age of the calves on the different CMR.

Age (days)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	19.8	20.7	1.96	0.651	NS

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 14 Average age of the calves on the different CP content concentrates.

Age (days)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	22.0	18.6	1.96	0.085	NS

Table 15 Average age of calves on each treatment.

Age (days)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	20.7	18.9	23.2	28.3	2.78	0.440	NS

8.2 Live weight

SB supplemented CMR had a significant increase (P<0.05) in LW of 1.4kg at week 1 on experiment compared to calves fed on control CMR regardless of concentrate CP level. There was no further significant differences due to CMR even through the numerical values were higher for SB CMR as shown in table 16. The calves fed control CMR experienced no compensatory weight increases.

Table 16 Effect of SB supplemented CMR on live weight.

Live Weight (kg)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	54.0	53.8	1.60	0.887	NS
1 week	55.9	57.3	0.52	0.010	*
3 weeks	66.3	67.3	1.00	0.332	NS
Weaning (week 6)	82.0	83.4	1.48	0.340	NS
12 weeks	132.8	135.5	4.14	0.523	NS
Increase in live wt	78.8	81.7			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Calves fed 160g/kg CP concentrate had numerically higher live weights up to weaning but 180g/kg CP concentrate fed calves had a higher weight at the finish as shown in table 17, however no statistical significance (P<0.05).

Table 17 Effect of 160g/kg and 180g/kg CP concentrate on live weight.

Live weight (kg)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	53.9	53.9	1.60	0.979	NS
1 week	56.8	56.5	0.52	0.528	NS
3 weeks	67.4	66.3	1.00	0.319	NS
Weaning (week 6)	83.4	82.1	1.48	0.390	NS
12 weeks	133.6	134.9	4.14	0.755	NS
Increase in live wt	79.7	81.0			

There was no significant differences (P<0.05) in the LW on each treatment as shown in table 18.

Table 18 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on live weight.

Live Weight (kg)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	54.6	53.5	53.4	54.2	2.26	0.562	NS
1 week	56.2	55.7	57.4	57.2	0.74	0.787	NS
3 weeks	67.6	65.1	67.1	67.5	1.42	0.155	NS
Weaning (week 6)	83.6	80.4	83.2	83.6	2.09	0.234	NS
12 weeks	132.0	133.6	134.9	136.0	5.87	0.959	NS
Increase in live wt	77.4	80.1	81.5	81.8			

8.3 DLWG

SB supplemented CMR had a significantly higher (P<0.05) DLWG in the first week of the experiment which was higher by 202g/day. The DLWG of these calves was also numerically higher over the whole experiment but to no degree of significance (P<0.05) as shown in table 19.

Table 19 Effect of SB supplemented CMR on DLWG.

DLWG (g/day)	Control CMR	SB CMR	s.e.d	P value	Sig
Start-1 week	287	489	74.5	0.010	*
1-3 weeks	743	713	65.8	0.647	NS
3-6 weeks	922	947	48.0	0.595	NS
Start - Weaning (week 6)	739	776	38.8	0.340	NS
Weaning - 12 weeks	1128	1161	71.6	0.648	NS
Start - 12 weeks	949	984	50.0	0.488	NS

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

There was no significant difference in DLWG of calve fed differing CP content concentrates. Calves fed 160g/kg CP concentrate had numerically higher DLWG from start to weaning however calves fed 180g/kg CP concentrate had experienced compensation and had numerically higher DLWG from weaning to 12 weeks and over the whole experiment, as shown in table 20.

Table 20 Effect of 160g/kg and 180g/kg CP concentrate on DLWG.

DLWG (g/day)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start-1 week	416	369	74.5	0.528	NS
1-3 weeks	752	703	65.8	0.465	NS
3-6 weeks	943	927	48.0	0.742	NS
Start - Weaning (week 6)	776	742	38.8	0.390	NS
Weaning - 12 weeks	1113	1177	71.6	0.383	NS
Start - 12 weeks	958	976	50.0	0.717	NS

No interaction between CMR and concentrate CP was experienced on the experiment however calves fed SB CMR had numerically higher DLWG over the whole experiment, shown in table 21.

Table 21 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on DLWG.

DLWG (g/day)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start-1 week	321	252	503	475	105.6	0.787	NS
1-3 weeks	817	670	692	733	93.2	0.162	NS
3-6 weeks	940	904	946	949	68.0	0.690	NS
Start - Weaning (week 6)	781	698	771	782	55.0	0.234	
Weaning - 12 weeks	1068	1187	1155	1167	101.5	0.459	NS
Start - 12 weeks	936	962	978	990	70.8	0.892	NS

8.4 Concentrate Intake

There was no significant effects (P>0.05) on concentrate due to CMR and concentrate CP level as shown in tables 22, 23, and 24. The intake from weaning cannot be analysed due to group housing of the calves.

Table 22 Effect of SB supplemented CMR on concentrate intake.

Concentrate Intake (kg)	Control CMR	SB CMR	s.e.d	P value	Sig
Daily intake start-weaning	0.76	0.78	0.06	0.712	NS
Total intake start-weaning	28.8	29.7	2.44	0.712	NS
Weaning-12 weeks intake	157.3	157.9			
Start-12 weeks	186.1	187.6			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 23 Effect of 160g/kg and 180g/kg CP concentrate on concentrate intake.

Concentrate Intake (kg)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Daily intake start-weaning	0.78	0.76	0.06	0.791	NS
Total intake start-weaning	29.6	28.9	2.44	0.791	NS
Weaning-12 weeks intake	155.2	160.0			
Start-12 weeks	184.8	188.9			

Table 24 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on concentrate intake.

Concentrate Intake (kg)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Daily intake start-weaning	0.79	0.72	0.77	0.80	0.09	0.450	NS
Total intake start-weaning	30.1	27.5	29.1	30.2	3.46	0.450	NS
Weaning-12 weeks intake	154.6	160.0	155.8	159.9			
Start-12 weeks	184.7	187.5	184.9	190.1			

There was no significant effect on concentrate intake when the calves were fed CMR as shown in tables 25, 26, and 27. Calves fed CMR supplemented with SB had numerically higher intake but not significant.

Table 25 Effect of SB supplemented CMR on concentrate intake in the first 5 weeks.

Average concentrate intake per head per day (g)	Control CMR	SB CMR	s.e.d	P value	Sig
Week 1	992	1219	204.8	0.274	NS
Week 2	2558	2653	370.8	0.797	NS
Week 3	4497	4837	478.4	0.480	NS
Week 4	7225	7142	588.8	0.890	NS
Week 5	8444	8605	778.2	0.839	NS

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 26 Effect of 160g/kg and 180g/kg CP concentrate on concentrate intake in the first 5 weeks.

Average concentrate intake per head per day (g)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Week 1	1038	1184	204.8	0.479	NS
Week 2	2500	2715	370.7	0.563	NS
Week 3	4652	4697	478.3	0.925	NS
Week 4	7396	6967	588.6	0.471	NS
Week 5	8579	8476	778.0	0.897	NS

Table 27 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on concentrate intake in the first 5 weeks.

Average concentrate intake per head per day (g)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Week 1	949	1036	1119	1319	290.1	0.786	NS
Week 2	2650	2466	2362	2944	525.4	0.310	NS
Week 3	4683	4311	4625	5050	677.8	0.412	NS
Week 4	7695	6756	7123	7161	834.2	0.414	NS
Week 5	8710	8177	8459	8751	1103.0	0.601	NS

8.5 Feed Conversion Ratio (FCR)

FCR was calculated by dividing concentrate and CMR intake by DLWG. Post weaning intakes could not be analysed due to being in group pens. There was no significant effect (P>0.05) on FCR from the treatments shown in tables 28, 29 and 30, however calves fed CMR supplemented with SB had numerically lower FCR. Calves fed 160g/kg CP had numerically lower FCR during CMR feeding but higher post weaning compared to 180g/kg.

Table 28 Effect of SB supplemented CMR on FCR.

FCR (kg)	Control CMR	SB CMR	s.e.d	P value	Sig
Start-weaning	1.82	1.75	0.04	0.152	NS
Weaning-12 weeks	3.54	3.45			
Start-12 weeks	2.73	2.65			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 29 Effect of 160g/kg and 180g/kg CP concentrate on FCR.

FCR (kg)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start-weaning	1.75	1.82	0.04	0.155	NS
Weaning-12 weeks	3.57	3.42			
Start-12 weeks	2.68	2.69			

Table 30 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on FCR.

FCR (kg)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start-weaning	1.75	1.88	1.75	1.76	0.06	0.193	NS
Weaning-12 weeks	3.70	3.38	3.45	3.45			
Start-12 weeks	2.74	2.73	2.63	2.66			

8.6 Wither Height

There was no significant effects (P>0.05) on wither height due to the treatments as shown in tables 31, 32 and 33, with all the results being numerically very similar.

Table 31 Effect of SB supplemented CMR on Wither Height.

Wither Height (cm)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	79.2	79.2	0.68	0.971	NS
Weaning (week 6)	86.7	87.2	0.76	0.513	NS
12 weeks	96.5	96.8	0.77	0.718	NS
Increase in wither height	17.3	17.6			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 32 Effect of 160g/kg and 180g/kg CP concentrate on Wither Height.

Wither Height (cm)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	79.5	79.0	0.68	0.465	NS
Weaning (week 6)	87.0	87.0	0.76	0.966	NS
12 weeks	96.5	96.8	0.77	0.645	NS
Increase in wither height	17.0	17.8			

Table 33 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on Wither Height.

Wither Height (cm)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	79.3	79.1	79.6	78.8	0.98	0.650	NS
Weaning (week 6)	87.2	86.2	86.8	87.7	1.08	0.235	NS
12 weeks	96.1	96.9	96.8	96.7	1.09	0.529	NS
Increase in wither height	16.8	17.8	17.2	17.9			

8.7 Heart Girth

Heart girth was measured just behind the front legs of the calf. There was no significant effects (P>0.05) on heart girth due to the treatments and the results are numerically similar.

Table 34 Effect of SB supplemented CMR on Heart Girth.

Heart Girth (cm)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	90.3	91.0	0.48	0.143	NS
Weaning (week 6)	103.6	104.3	0.74	0.377	NS
12 weeks	119.9	121.6	1.36	0.234	NS
Increase in heart girth	29.6	30.6			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 35 Effect of 160g/kg and 180g/kg CP concentrate on Heart Girth.

Heart Girth (cm)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	90.7	90.5	0.48	0.557	NS
Weaning (week 6)	103.8	104.1	0.74	0.674	NS
12 weeks	120.7	120.8	1.36	0.936	NS
Increase in heart girth	30.0	30.3			

Table 36 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on Heart Girth.

Heart Girth (cm)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	90.5	90.0	91.0	90.9	0.69	0.737	NS
Weaning (week 6)	103.8	103.4	103.8	104.7	1.05	0.400	NS
12 weeks	120.3	119.5	121.1	122.1	1.93	0.541	NS
Increase in heart girth	29.8	29.5	30.1	31.2			

8.8 Hip Height

Hip height was measured from the ground to top of hip bone, however there the treatments had no significant effect (P<0.05) on hip height.

Table 37 Effect of SB supplemented CMR on Hip Height.

Hip Height (cm)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	84.4	85.2	0.66	0.260	NS
Weaning (week 6)	92.3	92.6	0.63	0.617	NS
12 weeks	102.3	102.0	0.85	0.746	NS
Increase in hip height	17.9	16.8			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 38 Effect of 160g/kg and 180g/kg CP concentrate on Hip Height.

Hip Height (cm)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	84.6	85.0	0.66	0.554	NS
Weaning (week 6)	92.4	92.5	0.63	0.940	NS
12 weeks	102.0	102.4	0.85	0.616	NS
Increase in hip height	17.4	17.4			

Table 39 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on Hip Height.

Hip Height (cm)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	84.2	84.6	85.0	84.4	0.94	0.948	NS
Weaning (week 6)	92.5	92.0	92.3	92.9	0.89	0.389	NS
12 weeks	101.8	102.9	102.1	102.0	1.20	0.471	NS
Increase in hip height	17.6	18.3	17.1	17.6			

8.9 Hip Width

The hip was measures from the outer of each hip, there was no significant difference (P<0.05) in hip width due to the treatments, and the numerical values were very similar.

Table 40 Effect of SB supplemented CMR on Hip Width.

Hip Width (cm)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	27.5	27.4	0.36	0.634	NS
Weaning (week 6)	30.5	30.7	0.27	0.454	NS
12 weeks	35.8	36.1	0.43	0.597	NS
Increase in hip width	8.3	8.7			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 41 Effect of 160g/kg and 180g/kg CP concentrate on Hip Width.

Hip Width (cm)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	27.4	27.4	0.36	0.985	NS
Weaning (week 6)	30.6	30.6	0.27	0.965	NS
12 weeks	35.9	36.1	0.43	0.670	NS
Increase in hip width	8.5	8.7			

Table 42 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on Hip Width.

Hip Width (cm)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	27.5	27.5	27.3	27.4	0.52	0.950	NS
Weaning (week 6)	30.5	30.6	30.8	30.7	0.38	0.851	NS
12 weeks	35.7	36.0	36.0	36.1	0.61	0.763	NS
Increase in hip width	8.2	8.5	8.7	8.7			

8.10 Rumen Girth

Rumen girth was measures around the last rib as an estimation of rumen growth. There was no significant difference (P>0.05) in the treatments and the numerical values were very similar.

Table 43 Effect of SB supplemented CMR on Rumen Girth.

Rumen Girth (cm)	Control CMR	SB CMR	s.e.d	P value	Sig
Start	93.1	93.0	0.49	0.828	NS
Weaning (week 6)	116.7	117.4	1.05	0.601	NS
12 weeks	143.5	144.0	2.18	0.806	NS
Increase in rumen girth	50.4	51.0			

(***= P<0.001, **=P<0.01, *=P<0.05, NS = Not significant)

Table 44 Effect of 160g/kg and 180g/kg CP concentrate on Rumen Girth.

Rumen Girth (cm)	160g/kg CP	180g/kg CP	s.e.d	P value	Sig
Start	93.2	92.8	0.49	0.448	NS
Weaning (week 6)	117.1	117.1	1.05	0.973	NS
12 weeks	142.5	145.0	2.18	0.247	NS
Increase in rumen girth	49.3	52.2			

Table 45 Effect of SB supplemented CMR with 160g/kg or 180g/kg CP concentrate on Rumen Girth.

Rumen Girth (cm)	Control CMR & 160g/kg CP	Control CMR & 180g/kg CP	SB CMR & 160g/kg CP	SB CMR & 180g/kg CP	s.e.d	P value	Sig
Start	93.3	92.8	93.1	92.8	0.70	0.791	NS
Weaning (week 6)	117.2	116.4	117.0	117.8	1.48	0.458	NS
12 weeks	141.4	145.5	143.4	144.6	3.09	0.517	NS
Increase in rumen girth	48.1	52.7	50.3	51.8			

8.11 Calf Health

A parallel trial was carried out on the same calves as this trial but health aspects were observed and scored, these aspects included calf hydration, coughing, nasal and eye discharge and faecal consistency. Over the whole trial there was no significant difference in the health scores of the calves thus there was no health benefits observed between the treatments.

Throughout the experiment the calves were treated for signs of illness which was then acted upon, appendix 3 gives the medical treatments given to the calves on the experiment, and the information on the calves that died on experiment is in appendix 4.

9 <u>Discussion</u>

9.1 Calf Live Weight

The start weight of the calves on each treatment were blocked to each treatments hence no significant difference (P=0.887). The LW at week 1 was significantly higher (P<0.05) when the calves were fed SB supplemented CMR compared to the control, 57.3kg and 55.9kg respectively regardless of concentrate CP content. This results was reciprocated by Gorka *et al.,* (2009) also found that calves fed SB supplemented CMR had a significantly higher 26 day weight of life (P<0.05). Therefore suggesting SB improves performance and the results on these trials were a not coincidence. SB supplemented calves had a numerically higher LW over the whole trial and weighed an additional 2.8kg at 12 weeks but this was not a significant difference. Kelly *et al.,* (2014) found calves fed CMR supplemented with SB had a numerically higher weaning weight by 3.3kg, this trial matches this but the SB supplanted calves only weighed 1.4kg heavier.

The start weight of the calves on each CP concentrate was the same however at weaning the calves fed 160g/kg CP concentrate had a numerically higher weight of 83.4kg compared to calves fed 180g/kg who weighed an average of 82.1kg. Even though there was a 1.3kg average weight difference it was not significant (P=0.390). However, at 12 weeks a difference in LW of 1.3kg was observed but in favour of 180g/kg. Therefore this suggests calves fed 180g/kg concentrates experienced some compensatory growth from weaning onwards. Hill *et al.,* (2008b) also found no significant difference in LW in calves when fed concentrates containing 160 and 180g/kg CP. These results suggest there is only a small numerically performance advantage to feed 180g/kg and based on this experiments results 160g/kg CP concentrates should be fed from birth to weaning and 180g/kg CP concentrates should be fed post weaning for optimum LW.

There was no significant difference in LW between each individual treatment over the whole experiment even though calves fed SB supplemented CMR and 180g/kg CP concentrates numerically weighed 4.0kg heavier than those fed control CMR and 160g/kg CP concentrates at 12 weeks (P=0.959). However the calves fed SB supplemented CMR and 180g/kg CP were on average 7.6 days older than those calves fed control CMR and 160g/kg, but there was no significant differences in start age between the treatments (P=0.440). The calves on each treatment averaged 132-136kg LW at 12 weeks on trial which exceeded the target weights set by Dawson *et al.,* (not dated) of 102-105 at 12 weeks and 119-122 at 15 weeks. Therefore calf performance was not limited by being on the trial.

9.2 Calf DLWG

Calf DWLG was significantly higher from start to week 1 when calves were fed SB supplemented CMR compared to the control, 489g/day and 287g/day respectively regardless of concentrate CP. This increase was a large gain of 202g/day and was due to the SB inclusion because there was no significant difference in start weight (P=0.887), age at start (P=0.651) and concentrate intake (P=0.651), therefore indicating SB was the cause of the increase in DLWG. The overall DLWG was numerically higher when calves fed SB CMR however no level of significance. The DLWG from start to weaning was higher on this experiment than that recorded by Kelly *et al.,* (2014) as shown in table 46, this could be due to half the calves on this experiment being continental cross having potentially higher DLWG compared to all Holsteins used by Kelly *et al.,* (2014). Although Kelly *et al.,* (2010) found the DLWG from start to weaning was significantly higher when calves were fed SB CMR whereas this experiment only found a numerically higher DLWG however both experiments suggest SB might improve performance.

Table 46 Comparison in calf DLWG to weaning between the current trial and previous study.

DLWG (kg/day)	Kelly *et al.,* (2014)	Current experiment
Control	0.59	0.739
SB supplemented	0.69	0.776

The protein content of the concentrates showed no significant difference in DLWG which agrees with Hill *et al.,* (2008b) who looked at 160 and 180g/kg concentrates based on soya as the protein similar to this trial, found no significant difference in DLWG and feed conversion and intake. However in another trial by Hill *et al.,* (2008b) suggested that 160g/kg was the plateau post weaning with 180g/kg having numerically lower DLWG, however this experiment suggests that 180g/kg CP concentrates has numerically higher DLWG compared to 160g/kg. This experiment found that calves fed on 160g/kg CP concentrates had numerically higher DLWG from start to weaning when fed CMR. However post weaning calves fed 180g/kg CP concentrates had numerically higher DLWG to 12 weeks which suggests this is the optimum CP content of concentrates to feed calves. These results disagree with Hill *et al.,* (2008b) who concluded that CP content should decrease as calf grows and develops.

This trial found no significant difference in DLWG between the treatments. However, calves fed SB supplemented CMR and 180g/kg CP concentrates had numerically higher DLWG compared to the control CMR and 160g/kg CP concentrates, 990g/day to 936g/day respectively. This means there is no interaction between the CMR and the concentrates which give increased calf performance.

9.3 Performance Indicators

No significant difference was observed in rumen girth between the treatments which indicates rumen development was not affected by the treatments. These results are similar to Kelly *et al.,* (2014) and Guilloteau *et al.,* (2009) who euthanized the calves to determine rumen development and concluded that there was no increase in rumen development due to SB supplementation. Therefore this suggests there is no increase in rumen development during calf rearing when CMR is supplemented with SB. The CP content of the concentrates showed no difference in the performance indicators which was to be expected due to previous studies suggesting no effect would be seen.

Whilst no difference was observed in rumen girth, FCR was numerically lower over 12 weeks in calves supplemented with SB compared to the control, 2.65 compared to 2.73. This was also found by Guilloteau *et al.,* (2009) who found a trend (P=0.08) in feed conversion being improved by SB. No difference in FCR was found when the calves were fed 160 or 180g/kg CP concentrates which agrees with the literature which also found no difference.

9.4 Financial Appraisal

There is only a small difference in the cost to rear calves to 12 weeks on each treatment as shown in table 47 and 48. The cost per kilo of LW gain for calves fed differing concentrate CP levels regardless of milk powder was very similar over 12 weeks. However from start to weaning a 7p/kg saving was seen when fed 160g/kg CP concentrates, which equates to a saving of £1.96/calf when gains 28kg over this period.

SB supplemented CMR did reduce cost per kg of LW gain by 3p/kg over 12 weeks equating to £2.40/calf when gaining 80kg over this period. The feed conversion improvement in the SB calves will contribute to cheaper calf rearing despite the higher cost of the CMR is higher cost saving per kg of LW will result.

The treatment of feeding SB CMR and 160g/kg CP concentrate was the cheapest per kg of LW gain over the 12 weeks period by 3-5p for 80kg growth equates to £2.40-4.00/calf saving and £96-160 saving over 40 calves. The treatment that represents common practice by feeding control CMR and 180g/kg CP concentrates is the most expensive per kg of LW gain from start to weaning by 8-12p which for 28kg growth equates to £2.24-3.36/calf and a saving of £89.6-134.4 over 40 calves. This suggests standard practice is not the cheapest method to rear calves and there are possibilities to reduce cost without affecting performance.

Further research following the animals to slaughter is desired to determine the cost of kg of LW gain post 12 weeks to determine whether the treatments have any further fed cost effects.

Table 47 Financial appraisal of the performance of calves based on concentrate or CMR.

	160g/kg CP	180g/kg CP	Control CMR	SB CMR
Cost CMR (£/t)	1642.5		1,625.0	1,660.0
Cost Concentrate (£/t	298	304	301	
Average cost CMR/calf (£)	35.97	35.97	35.59	36.35
Average Intake (kg) start-weaning	29.6	28.9	28.8	29.7
Average cost concentrate/calf (£) (start-weaning)	8.82	8.78	8.67	8.94
Average Intake (kg) weaning-12 weeks	155.2	160.0	157.3	157.9
Average cost concentrate/calf (£) (weaning-12 weeks)	46.25	48.64	47.35	47.53
Average cost concentrate/calf (£) (start-12 weeks)	55.07	57.42	56.02	56.47
Total cost CMR+concentrate (£)	91.04	93.39	91.61	104.77
Average weight gain (start-weaning)	29.5	28.2	28.0	29.6
Average cost per kg live weight start-weaning	1.52	1.59	1.58	1.53
Average weight gain (weaning-12 weeks)	50.2	52.8	50.8	52.1
Average cost per kg live weight weaning-12 weeks	0.92	0.92	0.93	0.91
Average weight gain (start-12 weeks)	79.7	81.0	78.8	81.7
Average cost per kg live weight start-12 weeks	1.14	1.15	1.16	1.13

Table 48 Financial appraisal of the performance of calves based on treatment.

	Control CMR 160g/kg CP	Control CMR 180g/kg CP	SB CMR 160g/kg CP	SB CMR 180g/kg CP
Cost CMR (£/t)	1,625		1,660	
Cost Concentrate (£/t	298	304	298	304
Average cost CMR/calf (£)	35.59		36.35	
Average Intake (kg) start-weaning	30.1	27.5	29.1	30.2
Average cost concentrate/calf (£) (start-weaning)	8.97	8.36	8.67	9.18
Average Intake (kg) weaning-12 weeks	154.6	160.0	155.8	159.9
Average cost concentrate/calf (£) (weaning-12 weeks)	46.07	48.64	46.43	48.6
Average cost concentrate/calf (£) (start-12 weeks)	55.04	57.00	55.1	57.78
Total cost CMR+concentrate (£)	90.63	92.59	91.45	94.13
Average weight gain (start-weaning)	29.0	26.9	29.8	29.4
Average cost per kg live weight start-weaning	1.54	1.63	1.51	1.55
Average weight gain (weaning-12 weeks)	48.4	53.2	51.7	52.4
Average cost per kg live weight weaning-12 weeks	0.95	0.91	0.90	0.93
Average weight gain (start-12 weeks)	77.4	80.1	81.5	81.8
Average cost per kg live weight start-12 weeks	1.17	1.16	1.12	1.15

9.5 Limitations

There are a number of limitations and improvements that could be made to increase the accuracy of the experiment. When the performance indicators were measured, the calves were moving and impeding a high level of accuracy, an additional person to steady the calves could reduce this issue. Ideally the calves would be brought in at the same time of the same breed and weights rather than staggered to reduce any environmental effects and reduce effect of breed and start weight. Reducing the distance the calves travelled in order to reduce stress on the calves and any adverse effects on performance. The feed troughs could get tipped over and the calf's flicked food out of the buckets hence reduced accuracy of feed intake. Ideally the experiment would have an increased number of calves to reduce the natural variability however this was limited due to space and calf availability.

10 <u>Conclusion</u>

The null hypothesis stating SB has no effect on calf performance is rejected however the other two are accepted.

SB increased performance from start to week one and increased performance numerically over 12 weeks. Due to this experiment found that SB significantly increased ($P<0.05$) the DLWG from start to week one thus resulting in a significantly higher week 1 live weight. There was no significant difference ($P>0.05$) in calf performance when calves were fed 160 or 180g/kg CP concentrates, and there was no significant interaction ($P>0.05$) between the milk powder and CP content of the concentrates. SB however does not improve rumen development due to no significant difference observed in rumen girth.

All the treatments exceeded the DLWG performance targets stated by Charlton (2009), but the treatment with the highest numerical performance in relation to live weight and DLWG was CMR supplemented with SB and 180g/kg CP concentrates. However calves fed SB CMR and 160g/kg CP concentrates had the lowest cost per kg of live weight gain hence and therefore is the suggested method and treatment to rear calves. Also the performance of these calves was very similar to the highest performing treatment. The treatment most similar to common practice the control CMR and 180g/kg CP concentrates was the most expensive and poorest performance which suggests this is not the right method to rear calves at this current time. In times of fluctuating beef prices being able to manage variable costs when rearing cattle is essential.

Future work needs to be conducted using a larger number of calves to reduce the natural variability to test whether SB has a significant effect on calf performance, along with more work into the optimum CP content of calf concentrates. Follow on performance should be monitored to determine long term effects because a small gain at weaning could be large gain at slaughter, and possible further improvements in feed conversion to reduce feed costs. Also work into the effect of SB on different breeds to determine whether higher performance breed see additional benefit or not compared to lower performance breeds.

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12 Appendices

12.1 Appendix 1 Concentrate formulation

Name	160g/kg CP concentrate	180g/kg CP concentrate
Wheatfeed	25.00	29.70
Barley	19.05	16.80
Soya Hulls	13.30	13.30
Supaflow Beet Pulp	8.60	0.00
Hipro Soya	7.50	10.00
Vivergo Wheat Distillers	5.90	7.50
US Maize Distillers	5.00	6.60
SCM Maize Germ	5.00	5.00
Cane Molasses	5.00	5.00
Calcium Carbonate	2.80	3.25
Vegetable Oil	1.00	1.00
NuStart Premix	1.00	1.00
Salt	0.85	0.85
[VOLUME]	100.00	100.00

12.2 Appendix 2 Effect of breed and start weight

	Breed P value	**sig**	**Start Weight P value**	**sig**
LW (all)	<0.001	***	<0.001	***
DLWG				
Start-1 week	0.032	*	0.518	NS
1-3 weeks	0.171	NS	0.060	NS
3-6 weeks	0.191	NS	0.032	*
Start - Weaning (week 6)	0.022	*	0.011	*
Weaning - 12 weeks	0.114	NS	0.017	*
Start – 12 weeks	0.049	*	0.007	**
Concentrate Intake				
Start weaning	0.134	NS	<0.001	***
Week 1	0.121	NS	0.002	**
Week 2	0.086	NS	0.004	**
Week 3	0.175	NS	<0.001	***
Week 4	0.371	NS	<0.001	***
Week 5	0.256	NS	0.002	**
FCR				
Start-weaning	0.087	NS	0.010	*
Weaning-12 weeks	0.401	NS	0.033	*
Start-12 weeks	0.371	NS	0.061	NS
Wither Height				
Start	0.008	**	<0.001	***
Weaning (week 6)	0.177	NS	<0.001	***
12 weeks	0.821	NS	<0.001	***
Heart Girth				
Start	<0.001	***	<0.001	***
Weaning (week 6)	<0.001		<0.001	***
12 weeks	0.949	NS	<0.001	***
Hip Height				
Start	0.001	**	<0.001	***
Weaning (week 6)	0.044	*	<0.001	***
12 weeks	0.542	NS	<0.001	***
Hip Width (all)	<0.001	***	<0.001	***
Rumen Girth				
Start	<0.001	***	<0.001	***
Weaning (week 6)	0.008	**	<0.001	***
12 weeks	0.008	**	<0.001	***

12.3 Appendix 3 Medical treatment record.

Date	Calf number	Group	Treatment, dose and route of administration	Reason
7/10/2014	603399	C18	3.5 ml Norfenicol IM and 1.25ml Metacam SC	Coughing; temperature: 39.5°c
9/10/2014	603399	C18	3.5ml Norfenicol IM	Follow up dose
11/10/2014	403000	SB18	4.2ml Norfenicol IM	Coughing; temperature: 39.7°c
13/10/2014	403000	SB18	4.2ml Norfenicol IM	Follow up dose
15/10/2014	503405	SB16	15ml Baycox oral dose	Scouring; temperature: 39.1°c
16/10/2014	503405	SB16	3.2ml Norfenicol IM	Coughing; temperature 39.3°c
18/10/2014	503405	SB16	3.2ml Norfenicol IM	Follow up dose
20/10/2014	103422	C16	15ml Baycox oral dose	Scouring
	103018	C18	7ml Norfenicol SC and 1.25 ml Metacam SC	Coughing; temperature: 39.1°c
21/10/2014	103422	C16	3ml Norodine IM and 1 sachet Life-Aid Xtra	Scouring; temperature: 39.3°c
22/10/2014	103422	C16	1 sachet Life-Aid Xtra	Scouring
	103018	C18	7ml Norfenicol SC	Follow up dose
	307896	SB16	2.5ml Combiclav IM and 1.5ml Metacam SC	Calf dull and unresponsive; very high temperature: 40.1°c
23/10/2014	307896	SB16	2.5ml Combiclav IM	Follow up dose
24/10/2014	307896	SB16	2.5ml Combiclav	Follow up dose
27/10/2014	403028	SB18	4ml Norfenicol IM and 1.5ml Metacam SC	Coughing; temperature: 39.7°c
28/10/2014	103018	C18	3ml Combiclav IM and 1.5ml Metacam SC	Difficulty breathing
29/10/2014	403028	SB18	4ml Norfenicol IM	Follow up dose
	103018	C18	3ml Combiclav IM	Follow up dose
30/10/2014	103018	C18	3ml Combiclav IM and 1 sachet Life-Aid Xtra	Follow up dose; slightly dehydrated
31/10/2014	602995	SB16	4.6ml Norfenicol IM and 2ml Metacam SC	Coughing; temperature: 40.3°c
	103018	C18	3ml Norodine IM and 15ml Baycox oral dose	Scouring
2/11/2014	602995	SB16	4.6ml Norfenicol	Follow up dose
	403000	SB18	4.6 ml Norfenicol IM and 2ml Metacam SC	Coughing; temperature: 39.8°c
4/11/2014	403000	SB18	4.6 ml Norfenicol IM	Follow up dose
5/11/2014	307854	C16	2ml Dectomax SC	Control of parasites
7/11/2014	403028	SB18	4ml Norfenicol IM	Coughing and laboured breathing; temperature: 38.7°c
8/11/2014	603399	C18	4.5ml Norfenicol IM and 1.6ml Metacam SC	Coughing; temperature: 38.6°c
9/11/2014	403028	SB18	4ml Norfenicol IM and 1.3ml Metacam SC	Follow up dose
10/11/2014	603399	C18	4.5ml Norfenicol IM	Follow up dose
11/11/2014	403028	SB18	1.6ml Draxxin SC	Coughing; difficulty breathing
	307854	C16	20ml Vecoxan oral dose and 5ml Combivit IM	Scouring; treatment of coccidial infection

12/11/2014	403028	SB18	3ml Combiclav IM	Persistent infection; broad spectrum antibiotic effect
13/11/2014	403028	SB18	3ml Combiclav IM and 2ml Colvasone IM	Follow up dose; steroidal anti-inflammatory effect
14/11/2014	403028	SB18	3ml Combiclav and 1.4ml Metacam	Follow up dose
18/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
19/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
20/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
21/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
	708061	C18	15ml Baycox oral dose	Scouring
22/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
23/11/2014	307854	SB18	1 sachet Life-Aid Xtra	Scouring
	303431	C18	3.5ml Norfenicol IM and 1.6ml Metacam SC	Coughing; temperature: 39°c
25/11/2014	303431	C18	3.5ml Norfenicol IM	Follow up dose
	403453	C16	18ml Baycox oral dose	Scouring
26/11/2014	108055	SB18	1 tube Orbenin topically; 2.5ml Combiclav IM; 3.25ml Norfenicol and 1.75ml Metacam SC	Eye infection, high temperature: 40°c
27/11/2014	103450	SB16	3.5ml Norfenicol IM and 1.25 ml Metacam SC	Coughing; temperature: 39.5°c
28/11/2014	108055	SB18	3.5ml Norfenicol IM	Follow up dose
	403453	C16	3ml Norodine IM and 1 sachet Life-Aid Xtra	Scouring
29/11/2014	103450	SB16	3.5ml Norfenicol IM	Follow up dose
30/11/2014	608032	SB16	4.5ml Norfenicol IM and 1.75ml Metacam SC	Coughing; temperature: 39.3°c
2/12/2014	608032	SB16	4.5ml Norfenicol IM	Follow up dose
8/12/2014	508038	C18	4.7ml Norfenicol IM and 1.9ml Metacam SC	Coughing and difficulty breathing; temperature:38.6°c
10/12/2014	508038	C18	4.7ml Norfenicol IM	Follow up dose
15/12/2014	103018	C18	12ml Norfenicol SC	Coughing
16/12/2014	507863	SB16	16ml Norfenicol SC and 3ml Metacam SC	Coughing; temperature: 38.9°c
	208007	SB16	14ml Norfenicol SC and 2.5ml Norfenicol SC	Coughing; temperature: 38.9°c
	302999	SB16	14ml Norfenicol SC and 2.5ml Norfenicol SC	Coughing; temperature: 38.8°c
17/12/2014	703414	C18	15ml Norfenicol SC and 3ml Metacam SC	Coughing; temperature: 40.2°c
19/12/2014	403453	C16	8.5ml Norfenicol SC and 2ml Metacam SC	Coughing; temperature: 39.2°c
22/12/2014	307882	SB18	19ml Norfenicol SC and 3.5ml Metacam SC	Coughing
30/1/2015	508038	C18	20ml Norfenicol and 4ml Metacam SC	Coughing; temperature: 38.9°c

12.4 Appendix 4 Calf Deaths

Calf number	Date of death	Group	Age (days)	Time on experiment(days)	Cause of death
307854	28/11/2014	C16	89	57	Euthanised
603399	15/12/2014	C18	92	75	Suspected pneumonia