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THE EFFECT OF APPLICATION OF THE FAMACHA$^{©}$ SYSTEM ON SELECTED PRODUCTION PARAMETERS IN SHEEP

by

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I dedicate this to my husband

Declan Burke Leask

CONTENTS

LIST OF ABBREVIATIONS

ADG = Average Daily Gain

AM = Avermectin/Milbemycin anthelmintics

AR = Anthelmintic Resistance

BCS = Body Condition Score

BW = Body Weight

BZ = Benzimidazoles

CP = Crude Protein

epg = eggs per gram

FEC = Faecal Egg Count

FECRT = Faecal Egg Count Reduction Test

FMCH = FAMACHA$^{©}$ group

g = gram

kg = kilogram

LEV = Levamisole

MAR = Multiple Anthelmintic Resistance

MCP = Metabolisable Crude Protein

ME = Metabolisable Energy

ML = Macrocyclic Lactones

PPR = Periparturient rise (in FEC)

SD = Standard Deviation

ST = Strategic Treatment

STRAT = Strategically dosed group

SUPPR = Suppressively dosed group

TST = Targeted Selective Treatment

TT = Targeted Treatment

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SUMMARY

THE EFFECT OF APPLICATION OF THE FAMACHA$^{©}$ SYSTEM ON SELECTED
PRODUCTION PARAMETERS IN SHEEP

by

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A trial was conducted on a farm comprising a flock of approximately 300 Mutton
Merinos on which the FAMACHA$^{©}$ system was in use. Seventy five maiden and
multiparous ewes were blocked by class before being ranked by weight and then
randomly allocated using block randomization, with due regard to approximately equal
apportioning of the two classes of ewes, to the following three trial groups:

 (i) FAMACHA$^{©}$ (FMCH) group, in which only animals evaluated to be in FAMACHA$^{©}$
     categories 4 and 5 (overtly anaemic) were treated with levamisole HCl 2,5%
     (Nemasol NF, Intervet)

(ii) Strategically dosed (STRAT) group, blanket treated every six weeks with levamisole
     HCl 2,5% (Nemasol NF, Intervet)

(iii) Suppressively dosed (SUPPR) group, blanket treated at the same intervals with
      injectable moxidectin 1% (Cydectin, Bayer AH)

The trial was set to take place during the period of high haemonchosis risk (December to
April) but data was recorded from November 2006 to July 2007. However, the

deworming schedule of the trial only commenced in February 2007, due to Cydectin being out of stock until that time. All the trial animals were evaluated once weekly according to the FAMACHA$^{©}$ system, and Faecal Egg Counts (FECs) were performed on all groups prior to commencement of the trial, as well as during the trial period. Initial analysis of the results of all ewes, regardless of class, appeared to show that the FAMACHA$^{©}$ group gained, on average, 3-4 kg less (P<0.05) than the other two groups. However, these results compared groups which contained both pregnant and non-pregnant ewes.

Within each treatment regimen the multiparous ewes, which accounted for most of the pregnancies, were responsible for the largest difference in weight gains. Data from ewes that became pregnant during the trial period was separated from the data of non-pregnant ewes, and analysed because the pregnant ewes did not lamb down in the same week and cannot therefore be used as an accurate comparison as they were in different stages of pregnancy at any given time. The pregnant ewes' data was then ranked according to weeks before lambing and re-analysed. When the data was analysed separately for ewes that conceived during the trial and ewes that did not conceive, the results showed that there was no significant difference in weight gains amongst the three treatment regimens (Figure 4.2).

There were no significant differences in lamb weights (Table 4.3.3) nor average daily gains (ADG), as can be seen from Tables 4.4.1 to 4.4.3. Wool production was not analysed in this trial due to faulty sample collection at shearing, but ideally it should have been included.

Economic evaluation of the data initially showed that there appeared to be a benefit to dosing more frequently. During the trial period the total cost of deworming the SUPPR group was R163.51 and the liveweight gain gave an additional income of approximately R2758.00 resulting in a calculated financial gain of R2594.49 for 25 ewes when compared to the FMCH group. The cost of deworming the STRAT group for the trial period was R 104.65 and the liveweight gain gave an additional income of approximately

R2261.00 which resulted in a financial gain of R2156.35 in comparison to the FMCH group for 25 ewes. The cost for deworming the FMCH group was R10.96 for the duration of the trial. However, these calculations were based on both pregnant and non-pregnant ewe data combined and therefore do not accurately reflect the cost and return for the farmer of meat had the pregnant ewes data been analysed together with those that did not fall pregnant during the trial. Once the pregnant ewes were separated from the rest, there was no significant difference between the three groups regarding liveweight gain. Therefore there was no financial benefit to the farmer in deworming either suppresively or strategically and in fact resulted in an economic loss due to the cost of anthelmintic when compared to using the FAMACHA$^©$ system.

A shortage of feed due to unseasonal downpours leading to poor Body Condition Scores (BCS), forced the farmer to supplement the grazing and the FMCH group was able to make use of compensatory growth so that by the end of the trial, the was no significant difference in BCS between the groups.

The FAMACHA$^©$ system allows for selective targeted use of anthelmintics, and studies to date are contradictory on whether or not production is significantly affected by applying the FAMACHA$^©$ system to control *H. contortus*. However, this trial concluded that there is no significant difference in selected production parameters when using the FAMACHA$^©$ system as opposed to other methods of anthelmintic use in a Mutton Merino flock in a semi-intensive farming system. The FAMACHA$^©$ system is therefore the preferred method of worm control, where the major parasite problem is *Haemonchus contortus*, as other methods compared in this trial are not sustainable with regards to the worldwide increase in anthelmintic resistance (AR) and now with the increase in multiple anthelmintic resistance (MAR) on certain farms. It is also evident from this trial that the FAMACHA$^©$ system cannot be used in isolation as nutrition also plays a vital role in resistance and resilience of individual animals. Therefore if nutrition and other management practices are poor, the FAMACHA$^©$ system cannot be blamed for financial and production losses.

CHAPTER 1
INTRODUCTION

1.1 Introduction

The role of helminths in small stock production, and hence the correct use of anthelmintics to control helminth infections, has received much attention. Over time, newer and more effective anthelmintics have been produced that controlled worms effectively for decades, but total reliance on treatment was not sustainable and ultimately has been to the detriment of good farming practices and farm management. The indiscriminate use of these "wonder" drugs has in turn led to the development of widespread drug resistance in the helminth population. A growing number of farmers are now being forced to use additional or alternative methods to control the parasite burden in their stock as these drugs are no longer as effective as in the past.

The distinctive clinical effect of *Haemonchus contortus* infection is anaemia as a result of haematophagia and this can be used as an index of infection and the sheep's ability to cope with it. Much research has gone into developing a sustainable management tool for haemonchosis namely the FAMACHA[©] system (Van Wyk and Bath, 2002) as well as numerous studies by Van Wyk and others (1990, 1997, 2001, 2002, 2005, 2006, 2008). However, the financial implications of implementing this system have not been properly investigated previously.

The FAMACHA[©] system has been used with success in a number of countries outside of South Africa (Kaplan *et al*., 2004; Ejlertsen *et al*., 2006; Burke *et al*., Mahieu *et al*., 2007; Kenyon *et al*., 2009). Studies have shown that when sheep are infected with gastro-intestinal parasites there is a reduction in live weight gain (Coop *et al*., 1977, 1988; Hubert *et al*., 1979; Kenyon *et al*., 2009). These reports have led to some criticism of the FAMACHA[©] system based on the inference that it would lead to a decrease in production. Only limited research has been done to investigate whether there are any substantial deleterious production effects as a result of using the system. Without

substantial evidence, such claims either for or against the FAMACHA© system will remain speculative. Anthelmintic resistance is a growing problem that has affected most sheep and goat farmers to some extent, even subsistence farmers who make use of communal grazing, as these farmers are getting new stock from auctions or sales where the origin and previous management regarding helminth control is often unknown. Unfortunately these farmers are also getting advice from others at these sales that promote regular indiscriminate anthelmintic use.

The fact remains that the regular and simultaneous use of anthelmintics in entire flocks in an attempt to reduce worm burdens especially with regards to *Haemonchus contortus* is not a sustainable practice.

1.2 Objectives of the study

1.2.1 To measure selected production parameters in three systems, namely the FAMACHA© system, strategic dosing and suppressive dosing (used as the control).

1.2.2 To compare the results obtained from the FAMACHA© system with those obtained from the use of strategic and suppressive treatments.

1.2.3 To compare the cost to the farmer and the financial benefit (if any) for each treatment category.

1.3 Hypothesis

There is no financially or statistically significant difference in selected production parameters when applying the FAMACHA© system of control for haemonchosis compared with strategic and suppressive treatments.

CHAPTER 2

LITERATURE REVIEW

2.1 Anthelmintic resistance

Helminth problems in summer rainfall areas are primarily attributed to *Haemonchus contortus* and to a far lesser extent *Trichostrongylus spp*. (Bath *et al.*, 2005). Anthelmintic resistance (AR) is a worldwide problem. It has been reported in Australia, New Zealand, South Africa and Denmark (Waller, 1986; Bjørn *et al*., 1991; Maingi *et al.,* 1996). Studies in the United States show that resistance in *H. contortus* to many anthelmintics is becoming a serious problem (Kaplan *et al.*, 2004). There are reports on multiple anthelmintic resistance (MAR) on farms in the UK (Sargison *et al*., 2001, 2004, 2007; Cheng *et al*., 2003; Bartley *et al*., 2004) as well as unpublished reports of MAR in the south-east of Scotland, the north of England and Northern Ireland (Sargison *et al.,* 2007). Earlier work done in 2001 and 2004 by Sargison *et al* reported that populations of *Teladorsagia circumcincta* were already resistant to benzimidazole (BZ), levamisole (LEV) and macrocyclic lactone (ML) anthelmintics. There have even been reports of cross resistance between the imidothiazoles and the organophosphates (Sangster, 1996, 1999). In 2002 and 2003 Sutherland *et al* researched and discussed the resistance of *Teladorsagia circumcincta* to MLs in an attempt to find how this AR occurred and whether this was a dominant or recessive trait.

Factors that have contributed to the development of AR include frequent anthelmintic treatments, treating when parasites have a small refugia and using anthelmintics with similar modes of action for too long a period (Prichard *et al.,* 1980; Donald, 1983; Martin *et al.,* 1984; Waller and Prichard, 1986; Waller, 1986; Maingi *et al.,* 1996; Van Wyk, 2001).

There are also many published reports of populations of *H. contortus* with MAR in South Africa (Van Wyk *et al*, 1989, 1990, 1997b, 1998). Fears that it will not be long before

none of the current anthelmintics are effective have led to the development of targeted treatments (TT) best defined in Kenyon *et al* (2009) as "whole flock treatments given at the most appropriate times bearing in mind the need to maintain refugia".

Cringoli *et al* (2008) showed that just a single peri-parturient treatment and another at mid/end lactation showed a significant increase in milk production in dairy sheep. The distinction is also made between TT and strategic treatments (ST) which are usually administered from prior knowledge of when the parasite is most prevalent and are aimed at prophylactic treatment.

2.2 Targeted selective treatment (TST)

By only treating those animals which will benefit from treatment and leaving the rest of the flock untreated, the targeted treatments can be further enhanced (Malan *et al.*, 2001; Van Wyk and Bath, 2002; Van Wyk *et al*., 2006; Kenyon *et al*., 2009). This is known as targeted selective treatment (TST) which, even while treatments are being administered, provides a continual source of worms in refugia thus slowing the development of resistant parasites. Sources of refugia include any lifecycle stage in the host that is not exposed to a particular drug (Fleming *et al*., 2006; Kenyon *et al*., 2009).

Bath *et al* (2001) stated that the easiest and most practical laboratory measurement of the severity of anaemia in sheep is to measure haematocrit. However, they have shown that the FAMACHA$^©$ system of clinical anaemia evaluation provides a quick, simple, cost-effective and practical alternative to haematocrit measurements for estimating the severity of the *H. contortus* burden. An effective indicator for use in a TST programme should have the following criteria: Indicators should be cost-effective, simple to use, require minimal training of staff, and allow decisions to be made immediately ("sheep side") (Bisset *et al.,* 2001; Van Wyk and Bath, 2002; Riley and Van Wyk, 2009; Kenyon *et al,* 2009). The FAMACHA$^©$ system meets all the above criteria. Other indicators are mentioned which may be of some value but may not always meet all the criteria, for

example, dag scores, Faecal Egg Counts (FECs), milk production and live weight gain (Kenyon *et al*., 2009).

Kaplan *et al* (2004) found the FAMACHA$^{©}$ system to be a useful tool in the southern states of the United States wherever *H. contortus* is the primary parasite. This increases the worm population in refugia, but it was concluded that the FAMACHA$^{©}$ system should be integrated with other nematode control measures (Kaplan *et al*, 2004).

Unfortunately, the FAMACHA$^{©}$ system is only of use for haematophagous nematodes (and possibly liver flukes) therefore it is necessary to use an alternative method to assess sheep and goats for other nematodes. In these cases assessing live weight gains and body condition scores (BCS) have some benefit (Vatta *et al,* 1999, 2000; Bath *et al,* 2001; Van Wyk and Bath, 2002; Bath, 2006). A limitation of using BCS is that training is required and some people have difficulty in accurately estimating BCS. Mahieu *et al* (2007) concluded that older goats and those with poorer BCS at kidding required more dosing than younger animals and those with good BCS, and that FAMACHA$^{©}$ may be used as a practical culling tool.

2.3 Effects of TST on production

Bath and van Wyk (2002) have acknowledged that some loss of production could be expected with the use of the FAMACHA$^{©}$ system but that this still needed to be tested thoroughly. Studies in New Zealand on Romney sheep have shown an unfavourable genetic correlation between FEC and some production traits (Bisset and Morris, 1996), however, in Australia it was not found to be the case with Merinos with *H. contortus* burdens (Kahn *et al*, 2003). Eady *et al* (1998) correlated resistance to nematode parasites with production traits and found that parasite-resistant Merinos had relatively lower wool growth rate, but not body weight gain, and Morris *et al* (2000) showed that there was no negative effect on either wool growth or body weight gain in Romney sheep that were selected for resistance to nematode infection.

Bath *et al.* (2001) reported that treatment costs dropped by approximately 58% in those sheep that were managed according to the FAMACHA$^{©}$ system. Cringoli *et al* (2009) found similar results of a reduction in drug usage between 40% and 60%. However, they did not find a benefit to using the FAMACHA$^{©}$ system when compared to strategic prophylactic treatment, but that it has decided implications for sustainable worm control. Molento *et al* (2009) found that, when comparing the FAMACHA$^{©}$ system to a suppressive treatment, there were no significant differences in FECs or in reproductive indexes of parturition, birth rate, lamb weight and lamb mortality where *H. contortus* was the most prevalent species. This showed that naturally infected ewes could be raised with reduced anthelmintic use and that this would not impact negatively on their reproductive indices.

The principle behind the FAMACHA$^{©}$ system is that there are only a small number of animals in any given flock that have to be dewormed because they are unable to withstand the worm burden. Untreated animals void relatively large numbers of unselected worms back onto the pasture whilst the treated animals excrete only a small number of parasites. Thus the resistant worms are heavily diluted with unselected worms when the FAMACHA$^{©}$ system is used. This ensures the continuing efficacy of anthelmintics in specific flocks.

Kenyon *et al* (2009) reviewed methods of using the concept of refugia to decrease the development of drug resistance and concluded that targeting anthelmintic treatment on the basis of anaemia, milk production and live weight gain may be able to both maintain performance and decrease anthelmintic usage.

2.4 Alternative strategies

Nutritional demands during late gestation and lactation coincide with the periparturient rise (PPR) in FEC (Brunsdon, 1970; O'Sullivan and Donald, 1970; Connan, 1976; Lloyd,

1983; Kahn *et al.,* 2003). Liu *et al.* (2005) found that sheep less than 18 months of age that are resistant to nematode infections require more metabolisable energy (ME) as well as metabolisable crude protein (MCP) when dosed with *Trichostrongylus colubriformis* and *Teladorsagia (Ostertagia) circumcincta* larvae during a trial.

The magnitude of PPR may be decreased by selecting for resistant genotypes through selecting for sheep with low FEC (Woolaston, 1992; Kahn *et al*., 2003) and by improving nutrition (Donaldson *et al*., 1998, 2001; Kahn *et al*., 1999, 2003) as the increased requirement for metabolisable protein (MP) is greater in reproductive ewes than the requirement for ME. Houdijk *et al.* (2000) reported that beneficial effects of supplementing MP are not always observed. Supplementing ewes during the pre-partum period showed an increase in weight gain and a decrease in FEC (Kahn *et al*, 2003). This benefit lasted ten weeks after supplementation ceased and it was concluded that both genetic selection and protein nutrition could enhance host resistance during the peri-parturient period. They found that it benefited ewes to a point (especially ewes that had previously been suffering a weight loss) but for ewes that had a moderate weight gain, no benefits to resistance were observed. Therefore improving nutrition may help to improve both weight gains and resistance.

Louvandini *et al* (2006) found that supplementing the diet with high quality protein improved both resilience and resistance to natural infection by *T. colubriformis, H. contortus, Trichuris globulosa* and *Moniezia expansa* during the rainy season in Brazil. The likelihood is that it could show in FAMACHA© scores as well, as the FAMACHA© system selects for both resistance and resilience.

Thus, depending on the quality of available grazing, it may be desirable under specific circumstances to supplement ewes with good quality protein during the periparturient period in order to achieve weight gains and to aid with resistance and resilience (Janse van Rensburg, 2002).

Recent studies on developing a vaccine against *Haemonchus contortus* are still in the development stage (Smith, 2007 and LeJambre *et al*, 2008). The study by LeJambre *et al* (2008), was confounded by the presence of coccidiosis which resulted in lamb deaths, mostly from the group that had been vaccinated, and attempts by Smith (2007) to detect synergy between vaccination and anthelmintic used against a resistant strain of *H. contortus* were unsuccessful. A vaccine comprised of gut membrane proteins prepared from adult worms (LeJambre *et al*, 2008) shows potential but requires more research. Smith's work (2007) was an attempt to improve the efficacy of drugs against drug resistant worms whereas the FAMACHA[©] system attempts to avoid the development of drug resistant worms.

CHAPTER 3
MATERIALS AND METHODS

3.1 Experimental animals

Three farms were initially identified to take part in the trial. These farms included a commercial Mutton Merino farm near Delmas in Mpumalanga, a Pedi stud and a Dorper stud and commercial farm in Kameeldrift West in the North West Province. Unfortunately the Pedi farm worker did not date the data collected and did not keep to the protocol for deworming and therefore the data from that farm was excluded. The Dorper farmer was confused by the scoring between the FAMACHA$^{©}$ system (Figure 7.1) and BCS (Figure 7.2): a BCS of 1 being poor and 5 being fat whereas the FAMACHA$^{©}$ score of 1 being good and 5 being poor, and so, on occasion gave incorrect scores but could not remember when the mistakes had taken place. As a result, the Dorper farm data had to be excluded. The Mutton Merino farm followed the protocol and kept accurate records and so was used for the trial. This flock comprised approximately 300 Mutton Merinos (on which the FAMACHA$^{©}$ system was already in use).

Pregnant or lactating ewes have a temporary suppression of immunity and lambs/weanlings cannot yet mount an effective immune response to worm burdens (Brunsdon, 1970; O'Sullivan and Donald, 1970; Connan, 1976; Lloyd, 1983, Kahn *et al,* 2003) thus these groups are more susceptible to worm burdens and constitute good test individuals (Bath and Van Wyk, 2002). These animals were therefore chosen for the trial as far as possible.

The breeding system in place on the farm at the time of the trial was continued in order to produce results that would naturally occur in such a farming situation. The farmer used a twice-yearly breeding system. Rams were introduced into the ewe flock between November 2006 and December 2006 and again between March 2007 and April 2007 for a period of six weeks' duration for each breeding season.

A total of seventy five ewes was selected for the trial as follows: 15, 30 and 30 ewes were chosen from ewes born in August 2006, April 2006, and August 2005 respectively. Approximately the same number of multiparous and maiden ewes was allocated to each treatment group. The animals were ranked by weight and then allocated randomly to each group using block randomization.

The exclusion criteria used were: 1) animals over eight years of age and animals under 10 months of age

     2) animals suffering from any unrelated disease or condition that could affect the parameters measured

3.2 Experimental area

The farm is located in the Delmas area (26°2'35" S, 28°32'53" E), at an approximate altitude of 1570m, in the Mpumalanga Province, South Africa. *Haemonchus contortus* is the main parasite on the farm as indicated by larval culture (97%). This farm is situated in an area that is a summer rainfall area where the annual rainfall for the year was 347mm, the minimum temperature for the year was -5.6°C in June and maximum temperature for the year was 32.2°C during February (South African Weather Service, 2009).

3.3 Model system and justification of the model

The model could not be classified into any of the conventional epidemiological study models as it was a combination of a prospective cohort study and a case control study in the form of a field experiment (Thompson, 2005). It was decided that this would be the best method to obtain the data required to analyze the results and determine whether the FAMACHA[©] system should be implemented in terms of financial viability. The model is therefore best described as a Prospective Randomized Field Trial (Thompson, 2005).

3.4 Experimental design

The 75 animals were divided into the following different treatment groups, each comprising of 25: a) animals treated according to the FAMACHA$^{©}$ system (FMCH group), b) animals treated strategically every 6 weeks (STRAT group) and c) animals treated suppressively (SUPPR group).

The management of the three groups could not be separated for practical reasons and therefore the "strategic" group of sheep did not get the benefit from clean pastures as they may have if this system was being used on the entire flock. Results should indicate if, in the face of challenge, there is a significant benefit to treating all the sheep rather than targeted selective treatment using the FAMACHA$^{©}$ system. The remaining sheep (not included in the trial) were dosed according to the FAMACHA$^{©}$ system, therefore there was adequate larval challenge.

3.5 Experimental procedure

A Faecal Egg Count Reduction Test (FECRT) using the modified McMaster method (Reineke, 1973) was performed on the farm prior to the trial (test sensitivity level: one egg represents a count of 100 epg). A pooled larval culture was performed and the main parasite was *Haemonchus contortus* (97%). Other parasites identified by the larval culture were Oesophagostomum species (2%) and Trichostrongylus species (1%). The SUPPR group was injected every six weeks with moxydectin (Cydectin, Bayer) in the high risk times of the year (between February and June). The STRAT group was dosed every six weeks as commonly advocated in many programmes using a drug which had been proven to be effective by the FECRT, namely, levamisole (Nemasol, Intervet). Individuals in the FMCH group were only dosed if judged to be in FAMACHA$^{©}$ categories 4 or 5 according to the FAMACHA$^{©}$ chart (Bath *et al*., 2001) using levamisole (Nemasol, Intervet) or when there was submandibular oedema. The animals in all groups

were dosed according to individual body weight and according to the guidelines supplied in the information pamphlet for the dewormers. Faecal Egg Counts (FECs) were performed on all groups on 28 February 2007 when data collection commenced to ensure that there was sufficient worm burden. Body weight (BW) in kilograms, BCS (according to Figure 7.2) and FAMACHA$^{©}$ scores (according to Figure 7.1) were recorded weekly by the farmer who had been thoroughly trained in all subjective measurement methods. Lamb birth weights were recorded and ADG to weaning calculated. It was not possible to record wool production owing to a shortage of staff to weigh and collect samples during the shearing process. Ideally wool production should have been measured as a production parameter, but was not possible due to there being insufficient samples collected.

3.6 Management of project

Rams were introduced into the ewe flock born in August 2005 from 6 November to 18 December 2006, allowing for a six week spring/summer breeding period. Ewes found not pregnant when scanned by means of ultrasound technology 42 days after the rams were removed were included in the second breeding period which was from 5 March to 16 April 2007. The sheep graze on planted pastures, namely oats during the winter months and a mixture of Lucerne (*Medicago sativa*) and Smuts Finger grass (*Digitaria eriantha*) during the summer months. Additional supplementation by means of a pelleted ration is provided at approximately 250-500g per ewe per day when necessary (as indicated by BCS). Unseasonal downpours in April and June 2007 (Figures 7.4.1 to 7.4.3) prevented access to the pastures and this resulted in a substantial drop in BCS. The farmer then supplemented the ewes with ewe and lamb pellets (Afgri Animal Feeds, registration number V8173). Ewe and lamb pellet composition (g/kg): Protein 130g/kg (min); Crude Protein from NPN 30% (max); Urea 13.69 (max); Moisture 120 (max); Fat 25 (min); Fat 70 (max); Fibre 150 (max); Calcium 15 (max); Phosphorus 3 (min). The ewes were supplemented at approximately 250g to 500g per ewe per day from 7 May 2007 to 21 May 2007 when this was replaced by similar amounts of chocolate maize

(70kg yellow maize, 5ℓ water, 7kg sheep lick concentrate, 1.5kg slaked lime) due to a shortage of available cash flow. The maiden ewes born in April and August 2006 were separated from the main flock on 14 May 2007 and fed additional chocolate maize for the remainder of the trial period.

Body Condition Score: It is generally accepted that a BCS (Figure 7.2) may fall to 2 during certain stages of the production cycle (for example at weaning). Any animals falling below this score were fed supplementary feed and treated as required. Due to the grazing shortage, all animals were supplemented.

3.7 Data analysis

Body weight (liveweight), BCS, and FAMACHA[©] were recorded weekly and plotted over time (figures 4.1.1 to 4.3.4). For ewes that did not lamb during the trial, total liveweight gain throughout the trial period was calculated. For all ewes, an intermediate mass gain was calculated from day 0 until the first ewe lambed (interval liveweight gain). For ewes that were pregnant during the trial, liveweight gain was calculated and plotted from 21 weeks to one week before lambing (Figure 4.2).

For each of the trial ewes that lambed, lamb birth weights, weaning weights and days to weaning were recorded (Tables 4.4.1, 4.4.2, 4.5.1 and 4.5.2).

The effect of dosing strategy on liveweight gain, interval liveweight gain, lamb birth weight and ADG was estimated using multiple linear regression analysis (Tables 4.1.3, 4.2.3, 4.3.3, 4.4.3 and 4.5.3). Age group was included as a predictor in the models in order to adjust for confounding. In addition, sire was included in the models for lamb birthweights and ADG. For the pregnant ewes, the effect of dosing strategy on weight gain from conception to eight weeks before lambing was estimated using multiple regression, adjusting for age group.

Correlations between liveweight gain, BCS and FAMACHA$^{©}$ scores were estimated using partial correlation analysis, adjusting for ewe.

A significance level of $\alpha = 0.05$ was used throughout. All statistical analyses were done using the Stata 10.1 statistical programme (StataCorp, College Station, Texas, USA).

Costs of using anthelmintic products were calculated using current retail prices and actual dosages used per number of animals treated. Management (labour) costs were excluded as the farmer checked the flock on a weekly basis and therefore the labour did not dffer between groups. The financial benefits were calculated by multiplying differences in liveweight gains of each group, from the start to the end of the trial period, with current liveweight prices determined by the farmer to be R28/kg.

CHAPTER 4
RESULTS

4.1 Ewe data

The weekly body weights, BCS and FAMACHA$^©$ scores and the trends can be seen in figures 4.1.1 through 4.4.4. The liveweight data was analysed in order to establish whether there was a significant difference between the groups (Tables 4.1.3, 4.2.3, and 4.3.3). The FMCH group was compared with the STRAT and SUPPR groups. The SUPPR group was used as the control group since these ewes' production should not have been influenced by *H. contortus*. On FEC examination the SUPPR group had 0 epg for all counts with one exception of 200 epg. This showed that the use of moxidectin was effectively suppressing the *H. contortus* burden in the SUPPR group of ewes. The STRAT groups had slightly higher FECs than the SUPPR group but when the FECs were performed, the average counts for the group were very low per ewe (only in the hundreds). This indicated that levamisole (LEV) was still effective in this flock. The FMCH group showed both resistance and resilience as FECs were usually in the low thousands with the exception of one ewe with a FEC of 16 400epg. This ewe did not require dosing during the trial according to her FAMACHA$^©$ scores which indicated that, even though her worm burden was high, she demonstrated resilience.

4.1.1 Weight gains

Ewes that lambed down before the end of the trial were excluded from the analysis as they were removed from the flock upon lambing in order to allow the ewes and lambs to bond. Thus no further weights, BCS or FAMACHA$^©$ scores were collected which accounts for the discrepancy in the number of ewes in each category: only 18 ewes in FMCH group, 21 ewes in STRAT group and 21 ewes in SUPPR group.

Table 4.1.1 Group body weight gain from start to end of trial period

Subgroup	Mean body weight gain (kg)		
Birth month and year	**FMCH (SD)**	**STRAT (SD)**	**SUPPR (SD)**
August 2005	8.75 (2.36)	14.08 (2.33)	15.08 (1.28)
August 2005 (n)	n=6	n=6	n=6
April 2006	11.06 (5.70)	13.45 (4.23)	13.15 (4.27)
April 2006 (n)	n=8	n=10	n=10
August 2006	19.88 (2.02)	21.8 (1.48)	24.2 (1.99)
August 2006 (n)	n=4	n=5	n=5

Table 4.1.2 Body weight gain of all groups from start to end of trial period

FMCH (SD)	STRAT (SD)	SUPPR (SD)
12.25 (5.87)	15.62 (4.74)	16.33 (5.51)
n=18	n=21	n=21

n = number of animals

SD = standard deviation
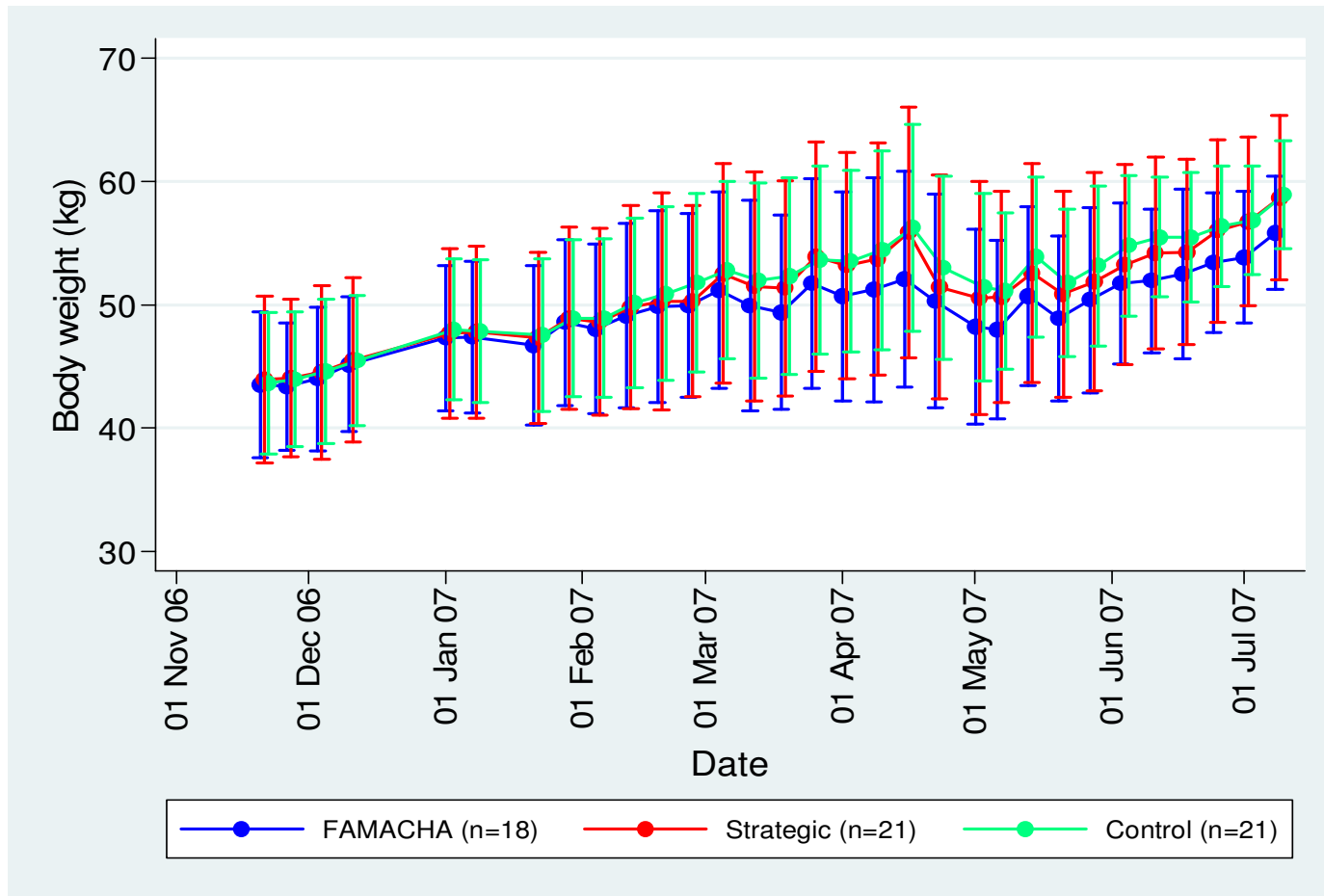
Figure 4.1.1 Mean body weights of all groups from start to end of trial period

Note: Control = SUPPR group
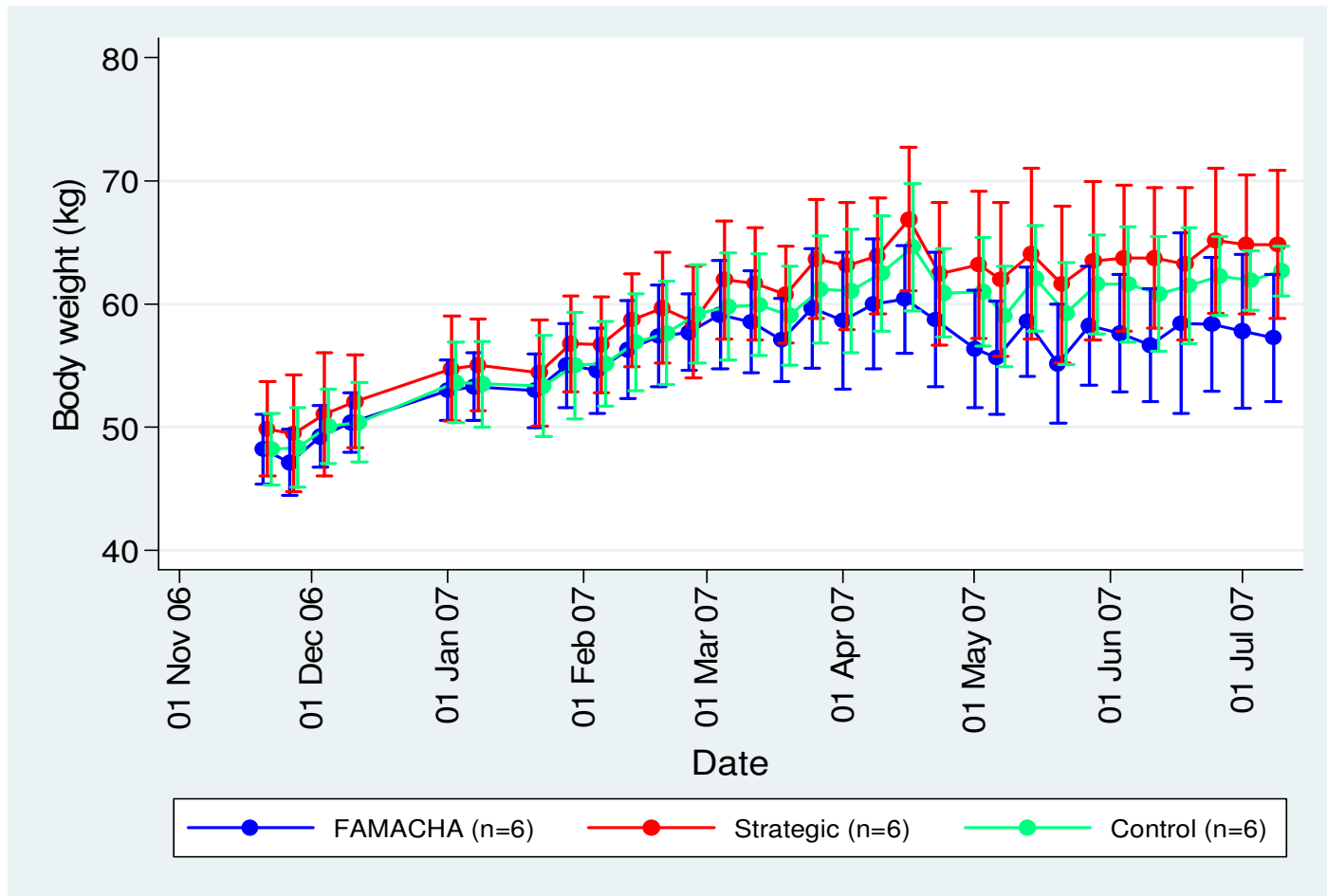
Figure 4.1.2 Mean body weights of ewes born in August 2005 from start to end of trial period
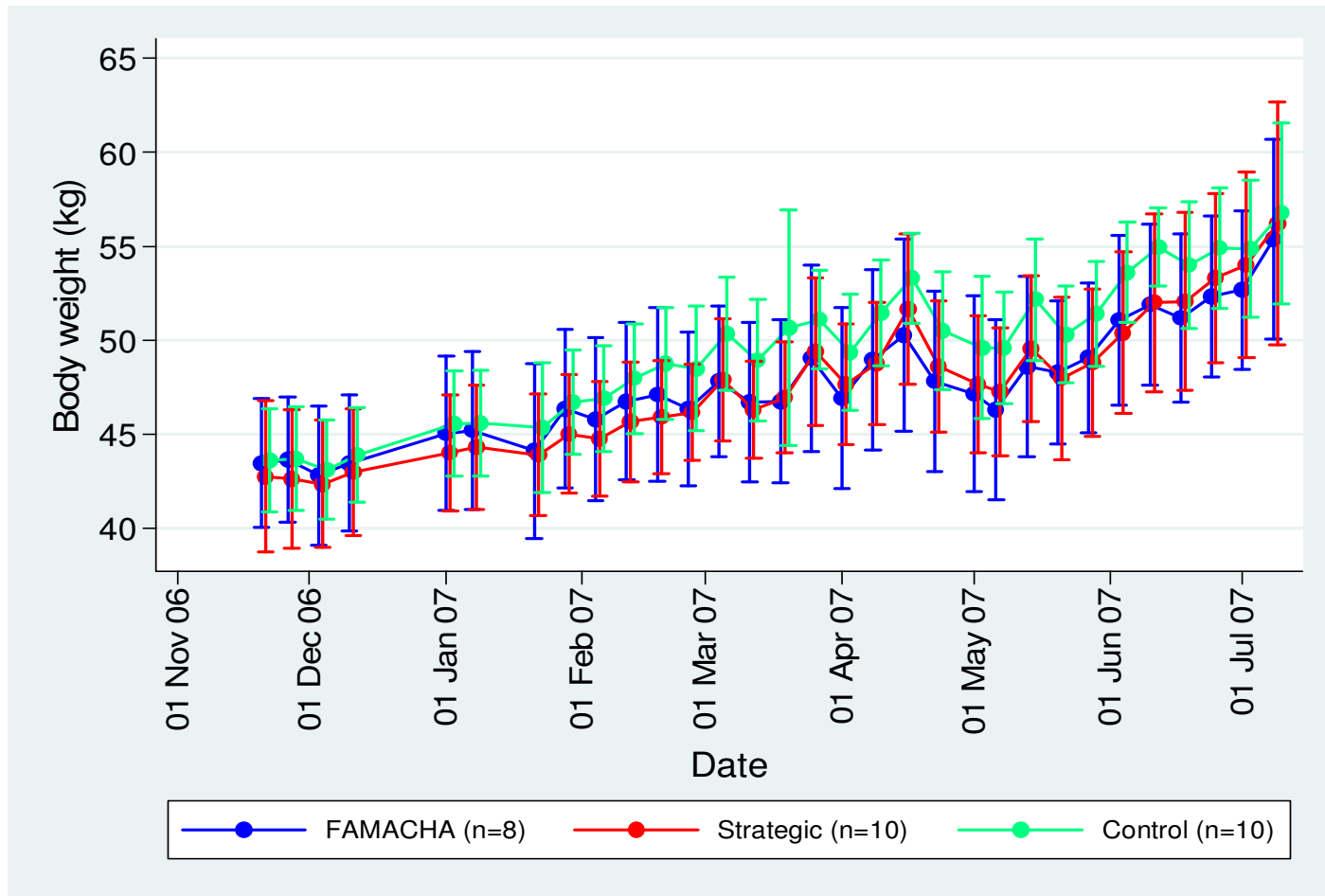
Note: Control = SUPPR group

Figure 4.1.3 Mean body weights of ewes born in April 2006 from start to end of trial period

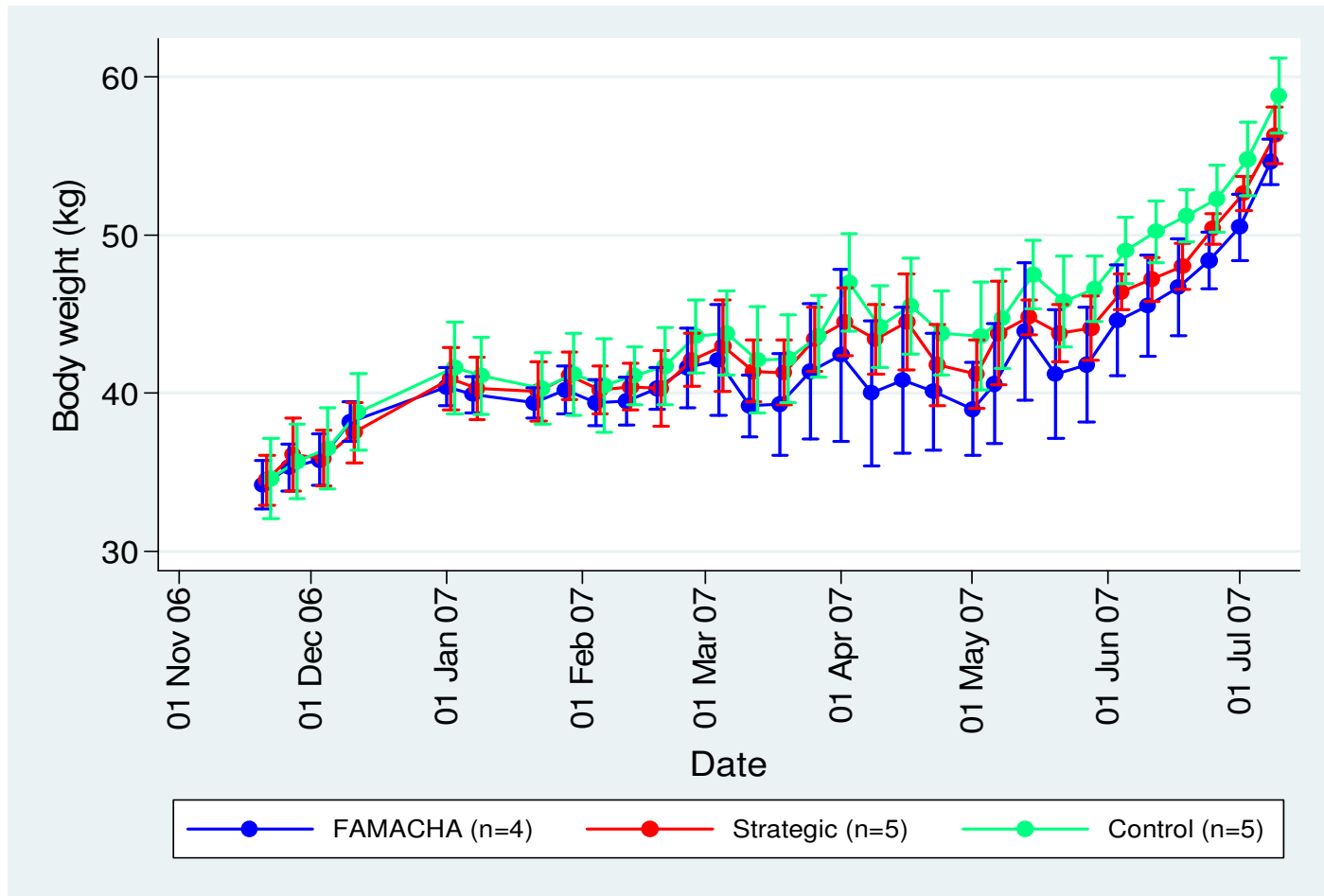**Note: Control = SUPPR group**

Figure 4.1.4 Mean body weights of ewes born in August 2006 from start to end of trial period

Note: Control = SUPPR group

Table 4.1.3 Multiple regression analysis of BW gain from start to end of trial

Group (n)	Coef. of Variance	95% Confidence Interval	P	Std. Err.
STRAT (21)	3.23	0.93 – 5.52	0.007	1.14
SUPPR (21)	3.94	1.65 – 6.23	0.001	1.14

When all data from ewes was pooled regardless of age and gestation there was a significant difference in total body weight (BW) gain between the STRAT group and the FMCH group (P=0.007) where ewes in the STRAT group gained on average 3.23 kg more over the trial period than the ewes in the FMCH group (Table 4.1.3). There was also a significant difference in BW gain between the SUPPR group and the FMCH group (P=0.001) as can be seen in Table 4.1.3. Ewes in the SUPPR group gained on average 3.94 kg more than the ewes in the FMCH group (Table 4.1.3). This can also be clearly seen in Figure 4.1.1. However, the mean body weight gains included all the ewes from the three different groups in the trial. From Figure 4.1.2 it is established that the ewes born in August 2005 were responsible for the apparent disadvantage of the FMCH group over the other groups. Figures 4.1.3 and 4.1.4 show that the maiden ewes (those born in April and August 2006) did not have a significant difference in weight gains between the STRAT, FMCH and SUPPR groups.

The above analysis included only ewes that did not lamb during the trial period as those that lambed were removed from the data set by the farmer. There was no significant difference in the weight gains until March 2007. After March 2007 it can be seen from Figure 4.1.1 to Figure 4.1.4 that the weight gains began to differ when the ewes started lambing around April 2007. Tables 4.2.1 and 4.2.2 below show the results from the weight gains of the ewes until the day when the first ewe lambed. There was still a significant difference in body mass gain from when the trial started until the first ewe lambed (P=0.023 for the STRAT group and P=0.001 for the SUPPR group) as can be seen in Table 4.2.3. However, this data set included ewes that were pregnant during the trial but may have lambed after the trial had ended. When analysis excluded all ewes that were pregnant or lambed during the trial period there was no significant difference in body weight gains (Table 4.3.3).

Table 4.2.1 Group body weight gain from start until first ewe lambed

Subgroup	Mean body weight gain (kg)		
Birth month and year	**FMCH (SD)**	**STRAT (SD)**	**SUPPR (SD)**
August 2005	11.67 (3.89)	14.05 (2.19)	14.30 (2.69)
August 2005 (n)	n=9	n=10	n=10
April 2006	5.50 (2.75)	6.00 (2.3)	7.85 (1.81
April 2006 (n)	n=10	n=10	n=10
August 2006	5.80 (4.44)	8.90 (1.71)	9.60 (1.39)
August 2006 (n)	n=5	n=5	n=5

Table 4.2.2 Body weight gains of all groups from start until first ewe lambed

FMCH (SD)	STRAT (SD)	SUPPR (SD)
7.88 (4.55)	9.80 (4.24)	10.78 (3.65)
n=24	n=25	n=25

n = number of animals
SD = standard deviation

Note: The first ewe to lamb was from the FMCH group and was removed from the data set to allow for bonding to occur. Therefore there are only 24 ewes in the FMCH group and 25 in the STRAT and SUPPR groups. This data set includes all data gathered until the first ewe lambed.

Table 4.2.3 Multiple regression analysis of body weight gain from start until first ewe lambed

Group (n)	Coef. of variance	95% Confidence interval	P	Std. Err.
STRAT(25)	1.77	0.25 – 3.28	0.023	0.76
SUPPR (25)	2.75	1.23 – 4.26	0.001	0.76

It can be seen from Tables 4.2.1 to 4.2.3 that there was still a significant difference between the FMCH group and the STRAT group (P=0.023) with a weight difference of 1.77 kg. Tables 4.2.1 to 4.2.3 show a significant difference between the FMCH group and the SUPPR group as well where the SUPPR group on average gained 2.75kg more than the FMCH group (P=0.001). However, this data set included ewes that were pregnant until the first ewe lambed. It was decided that any ewe that lambed down during or shortly after the trial period should be excluded from the data and analysed separately.

When the gestation / lambing period of the ewes that lambed were synchronized (with the week of lambing designated week 0), there was no significant difference between the different groups in BW gain as can be seen in Figure 4.2 and Tables 4.3.1 to 4.3.3 below.
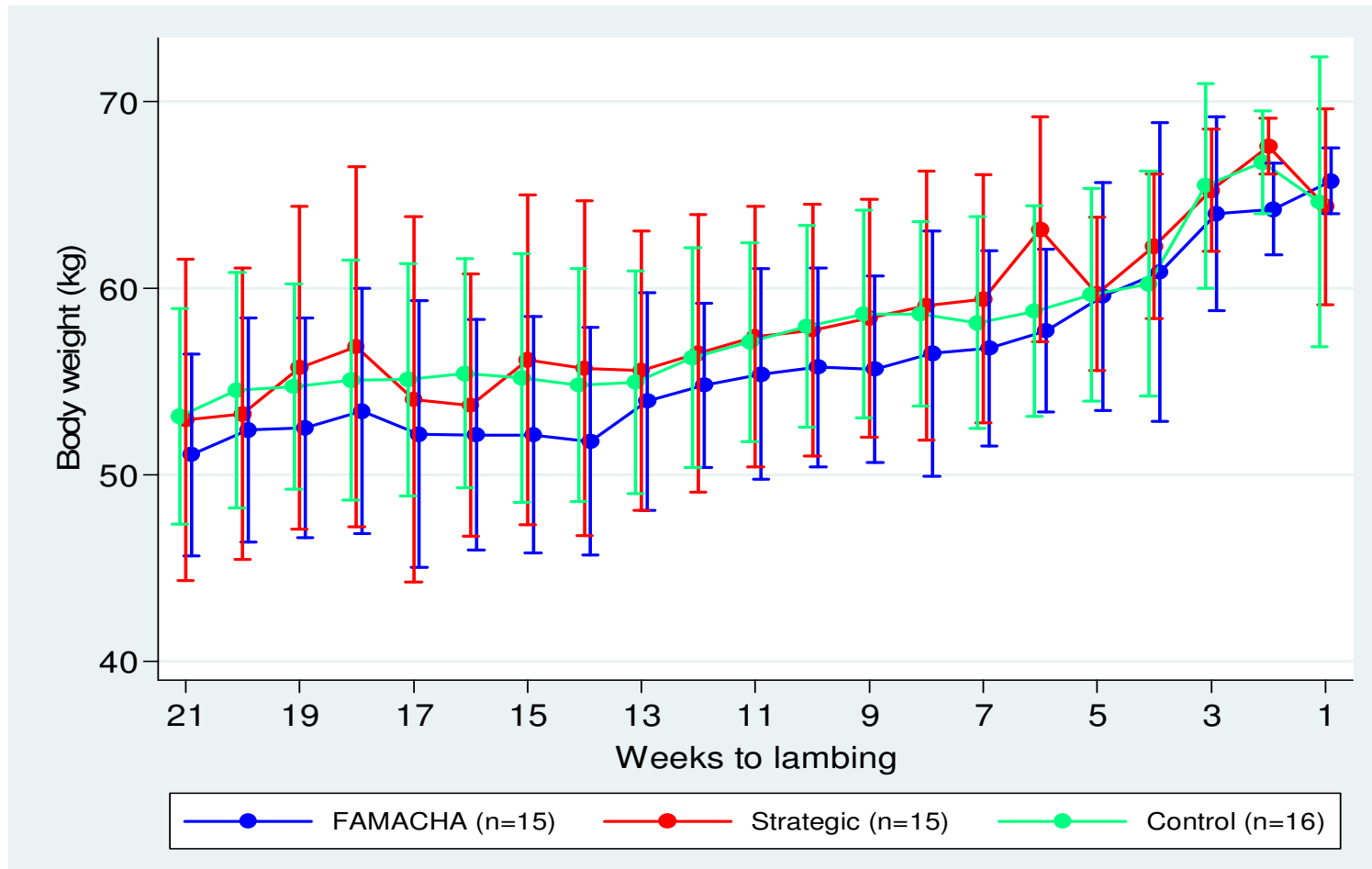
Figure 4.2 Mean body weights for ewes during pregnancy

Note: Control = SUPPR group

Table 4.3.1 Group body weight gains from 21 weeks to 8 weeks prior to lambing for trial ewes that lambed

Subgroup	Mean body weight gain (kg)		
Birth month and year	**FMCH (SD)**	**STRAT (SD)**	**SUPPR (SD)**
August 2005	6.44 (7.00)	6.78 (5.59)	6.00 (4.63)
August 2005 (n)	n=9	n=9	n=9
April 2006	2.00 (0.84)	5.17 (2.11)	4.86 (1.41)
April 2006 (n)	n=6	n=6	n=7

Note: Of the ewes born in August 2005 all those allocated to the FMCH group lambed, one of the ewes allocated to the STRAT group did not lamb and one of the ewes allocated to the SUPPR group did not lamb. Of the ewes born in April 2006, four of those allocated to the STRAT group did not lamb and three allocated to the SUPPR group did not lamb.

Table 4.3.2 Body weight gains of all groups from 21 weeks to 8 weeks prior to lambing

FMCH (SD)	STRAT (SD)	SUPPR (SD)
4.67 (5.78)	6.13 (4.48)	5.50 (3.55)
n=15	n=15	n=16

n = number of animals
SD = standard deviation

Table 4.3.3 Multiple regression analysis of body weight gain from 21 weeks to 8 weeks prior to lambing

Group (n)	Coef. of variance	95% Confidence interval	P	Std. Err.
STRAT (15)	1.47	-1.896 – 4.829	0.384	1.67
SUPPR (16)	0.92	-2.389 – 4.233	0.577	1.64

4.1.2 Body Condition Scores

BCS was not analysed using linear multiple regression but was rather plotted against time (Figures 4.3.1 to 4.3.4). The trends in the BCS support the evident shortage of grazing during May, June and July 2007 due to the rainfall (Figure 7.4.2) as a clear decrease in BCS coincides with this period and began just before the first ewe lambed down.

The decline in BCS in all three groups including the SUPPR from April through July is apparent in Figures 4.3.1 through 4.3.4. The lack of grazing due to the unseasonal heavy rainfall (Figure 7.4.2) when the farmer intended to graze his pastures, had a severe impact on the ability of some of the ewes to maintain BCS. All ewes were supplemented initially with a pelleted ration varying from 250g to 500g per ewe per day and later with chocolate maize at 500g per ewe per day. The youngest group of ewes (those born in August 2006) was separated from the main flock and fed additional maize. This allowed for the improvement in BCS from mid-May as can be seen from Figure 4.3.4.

The group that appears to have benefited the most from the supplementary feeding, in the August 2006 group of ewes, is the SUPPR group, which showed an almost immediate improvement in BCS. However, compensatory growth by the FMCH and STRAT groups resulted in no significant differences in BCS between the three groups at the end of the trial period. The initial difference may have been due to the suppressive worm control in the SUPPR group compared to the other two groups (Figure 4.3.4). This supports the results of Kahn *et al.* (2003) who demonstrated that supplementing ewes with good quality protein and energy only benefited those in poor condition. In this case it appears that the ewes without a worm burden were able to utilise the additional nutrition into

improving BCS. Those that had a worm burden in addition to the poor nutrition were able to only make full use of the supplementation at a later stage with regards to BCS. It seems likely that the additional nutrition played a role in stimulating both resistance and resilience in these ewes (as was found by Louvandini *et al* (2006)). Therefore, when ewes have lower worm burdens, they are better able to convert supplementary feed into BCS than ewes that have a higher worm burden.

A partial correlation analysis between mean BCS of all groups (Figure 4.3.1) and mean body weight of all groups from day 0 to the end of the trial (Figure 4.1.1) showed a highly significant (P<0.001) negative correlation (r = -0.5199).
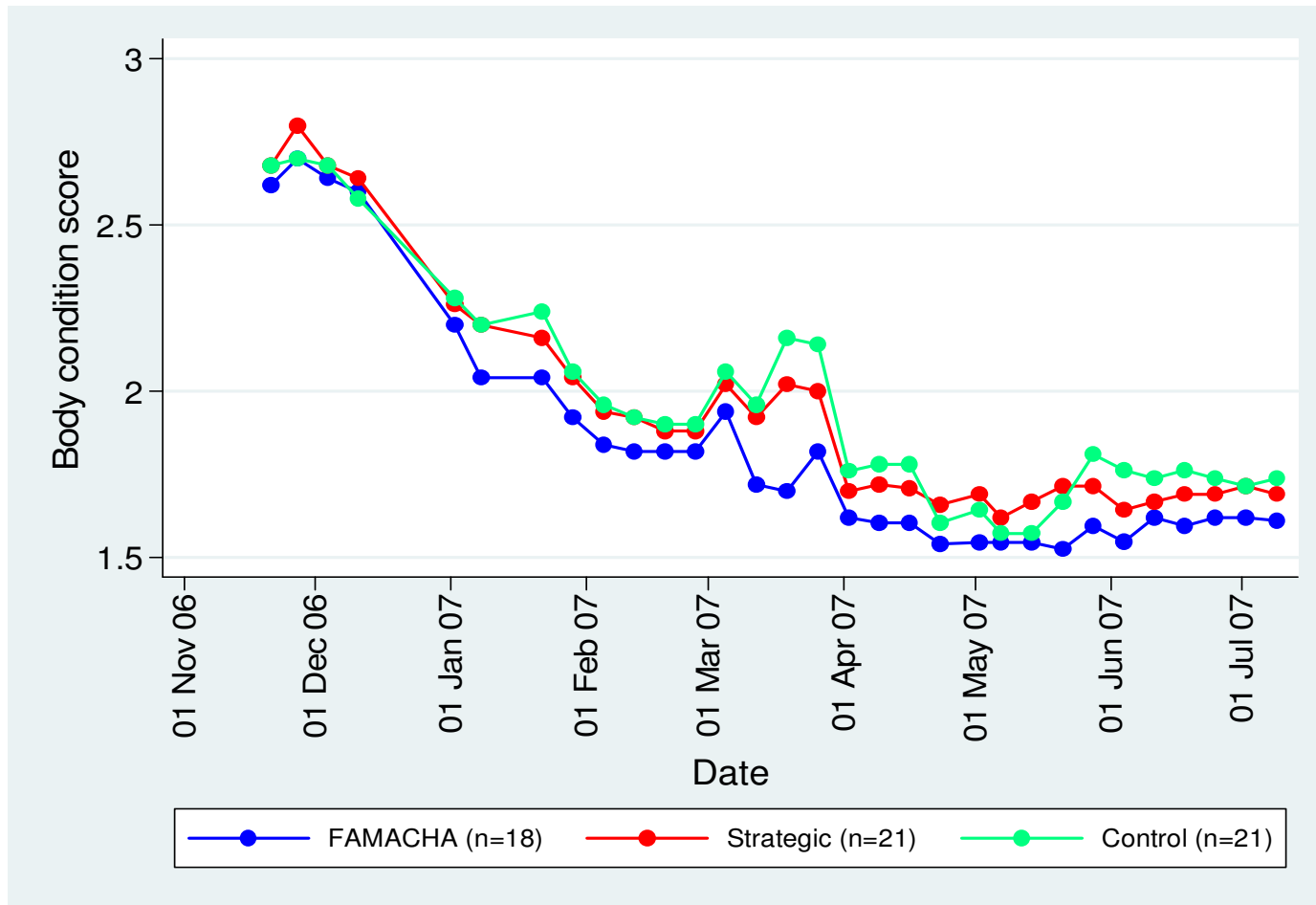
Figure 4.3.1 Mean body condition scores for all groups from start to end of trial period

Note: Control = SUPPR group

Figure 4.3.2 Mean body condition scores for ewes born in August 2005 from start to end of trial period

Note: Control = SUPPR group

Figure 4.3.3 Mean body condition scores for ewes born in April 2006 from start to end of trial period
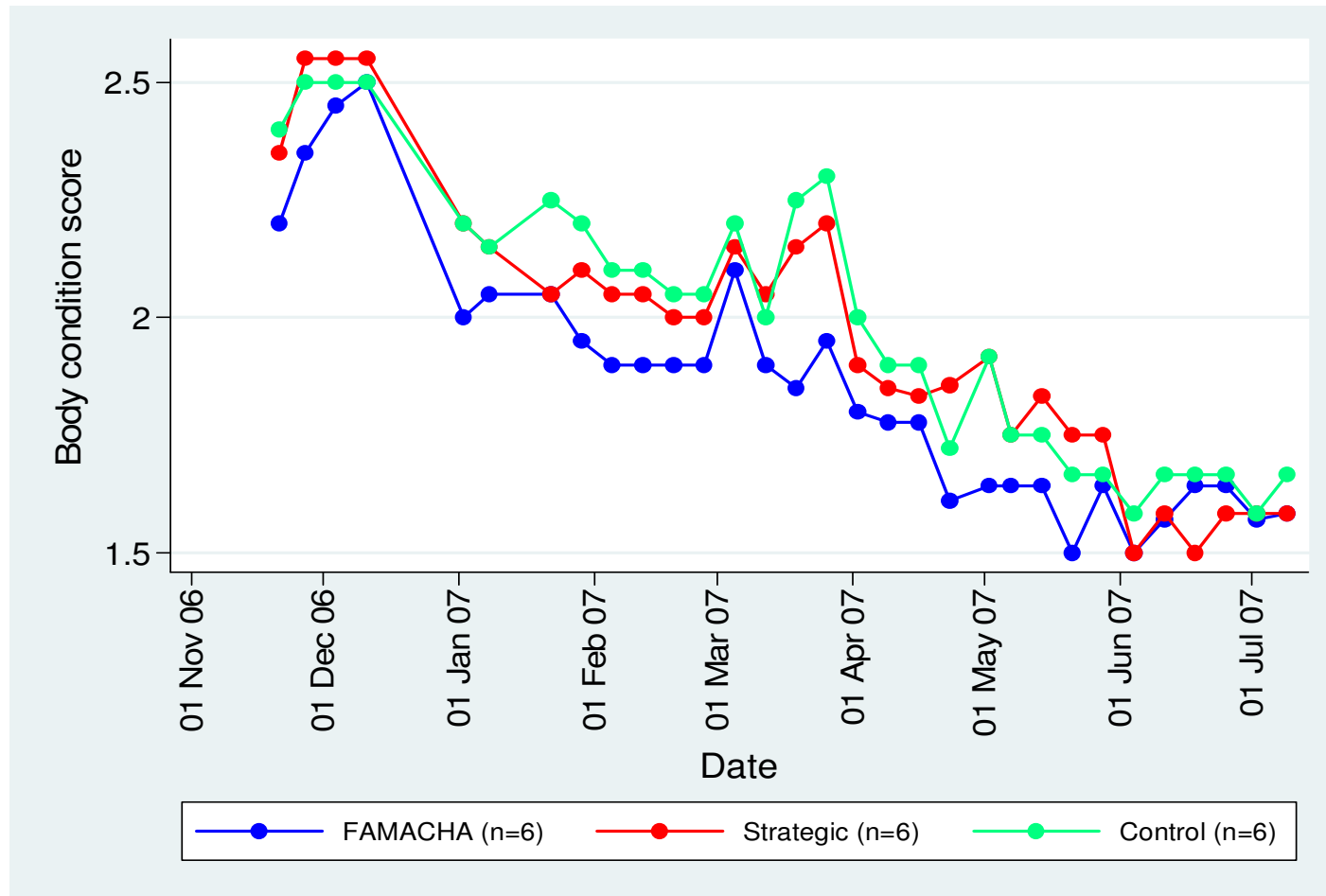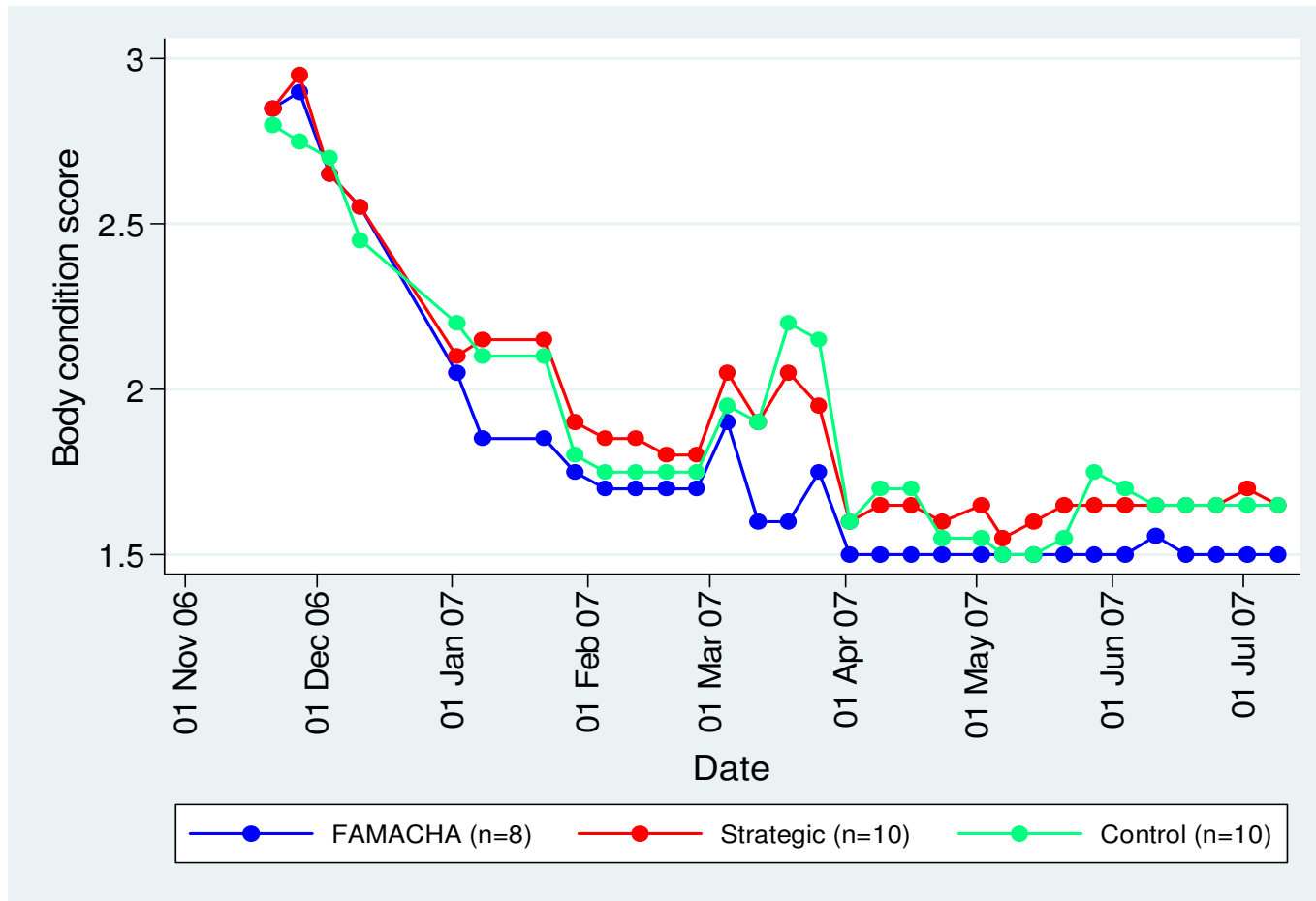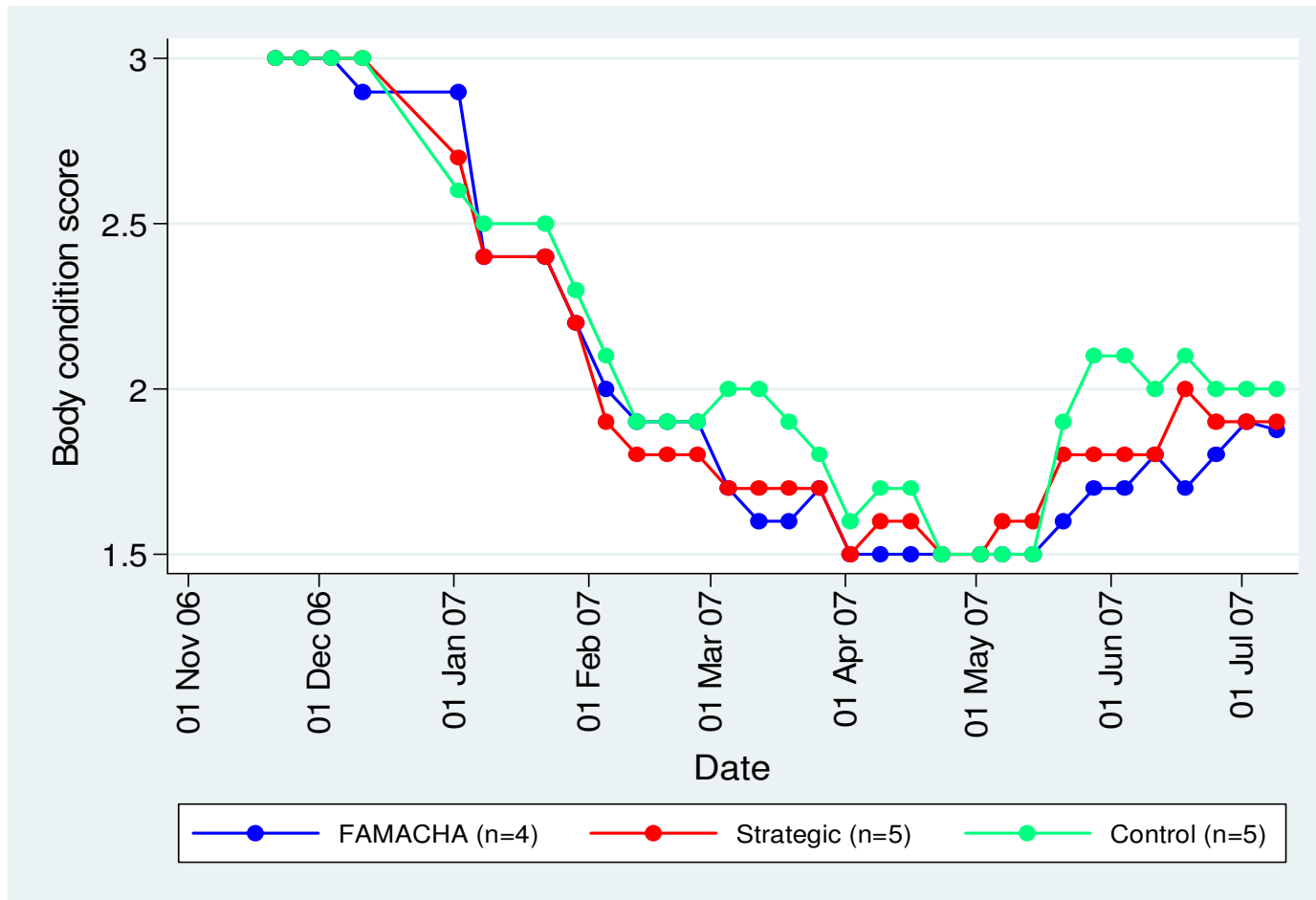
Note: Control = SUPPR group

Figure 4.3.4 Mean body condition scores of ewes born in August 2006 from start to end of trial period

Note: Control = SUPPR group

4.1.3 FAMACHA© Scores

On 12 March 2007, five ewes were seen to have bottle jaws. All five ewes belonged to the FMCH group. Four of the ewes had FAMACHA$^©$ scores of 3 and one had a FAMACHA$^©$ score of 4. These ewes were all dosed.

Mean FAMACHA$^©$ scores for all groups over the trial period (Figure 4.4.1) increased reciprocally with a decrease in BCS (Figure 4.3.1) when the ewes were lambing (Figure 4.1.1). This can probably be attributed to a combination of PPR and poor nutrition.

Figure 4.4.2 shows that FMCH and SUPPR groups appeared to have no marked difference for the older ewes. The STRAT group had better mean FAMACHA$^©$ scores by the end of the trial though there was still no marked difference in all three groups. Similar changes in FAMACHA$^©$ scores can be seen in Figures 4.4.1 through 4.4.4 that coincides with the period of food shortage.

A partial correlation analysis of BCS and FAMACHA$^©$ scores showed a highly significant (P<0.001) negative correlation (r = -0.2750).

A partial correlation analysis of FAMACHA$^©$ scores was performed against BW and the result showed a highly significant (P<0.001) positive correlation (r = 0.2725).
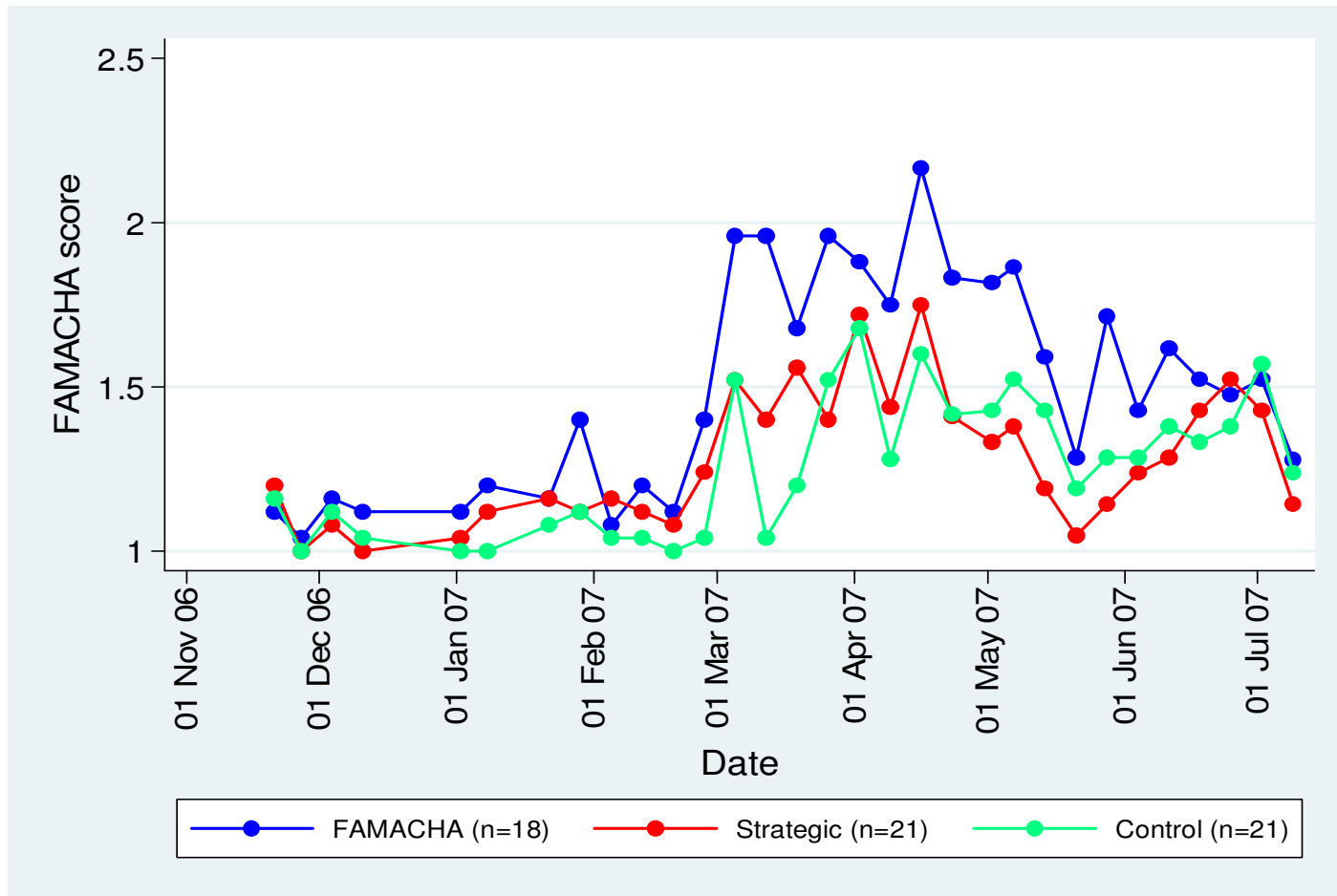
Figure 4.4.1 Mean FAMACHA© scores for all groups from start to end of trial period

Note: Control = SUPPR group

Figure 4.4.2 Mean FAMACHA$^{©}$ scores for ewes born in August 2005 from start to end of trial period

Note: Control = SUPPR group

Figure 4.4.3 Mean FAMACHA$^{©}$ scores for ewes born in April 2006 from start to end of trial period
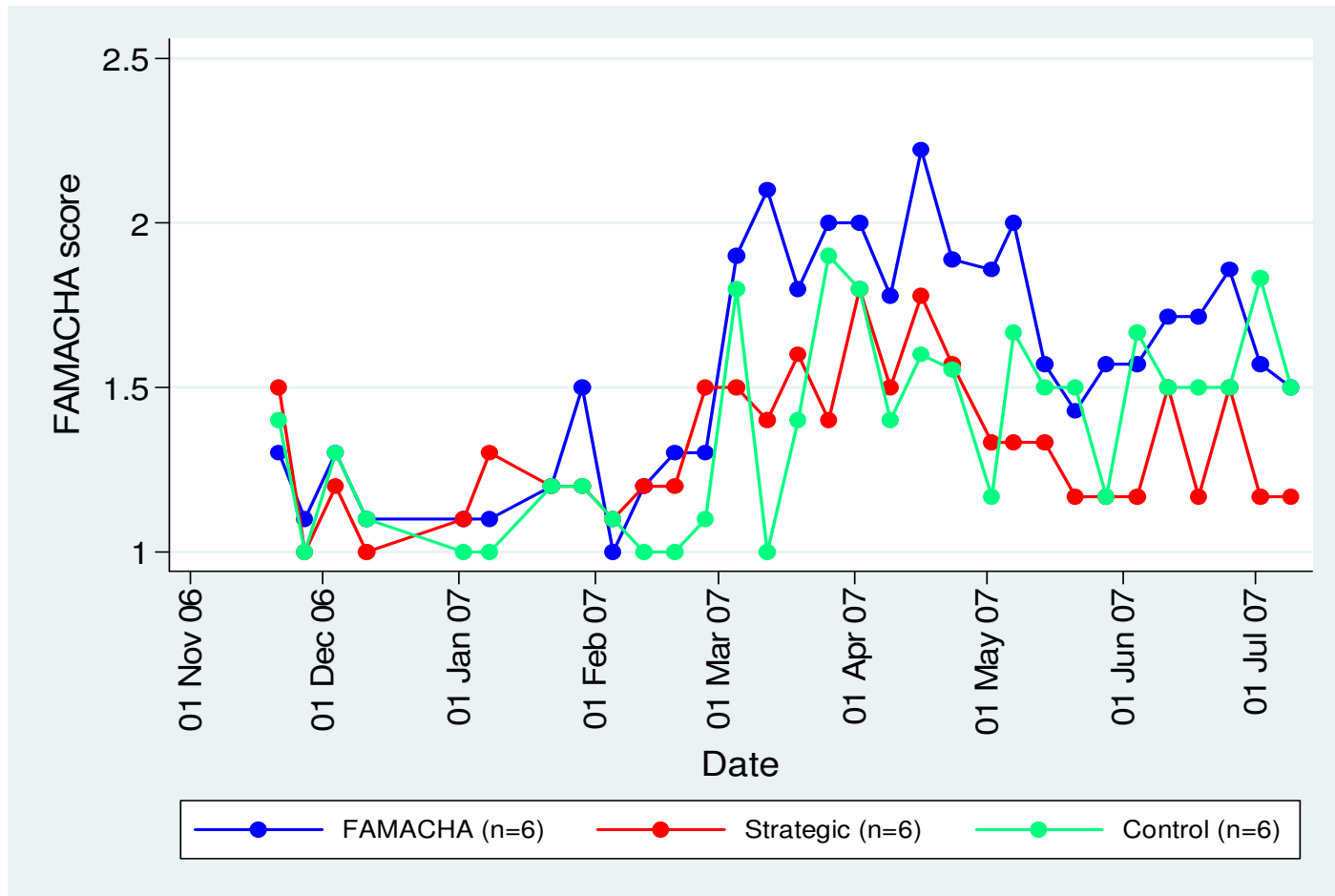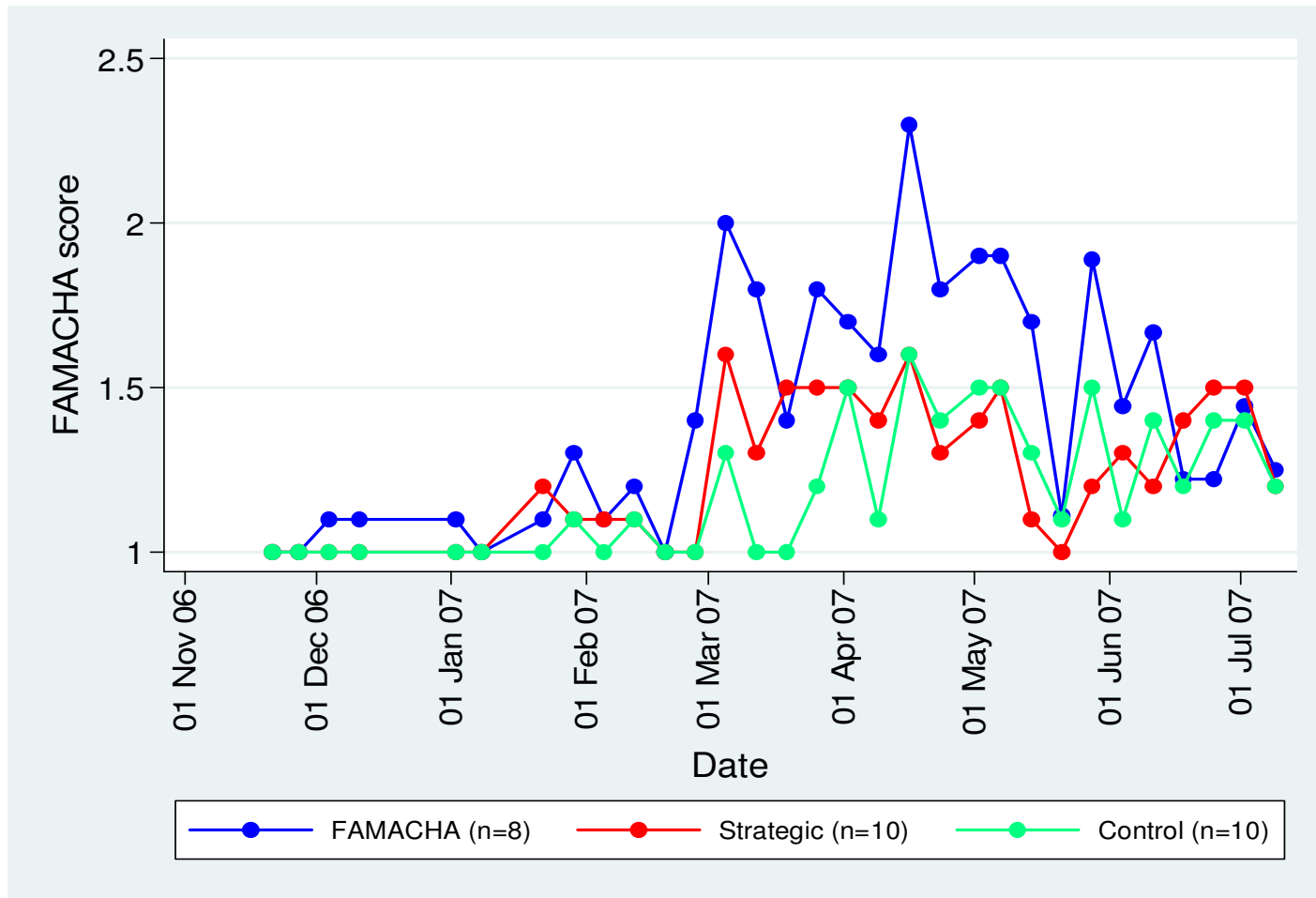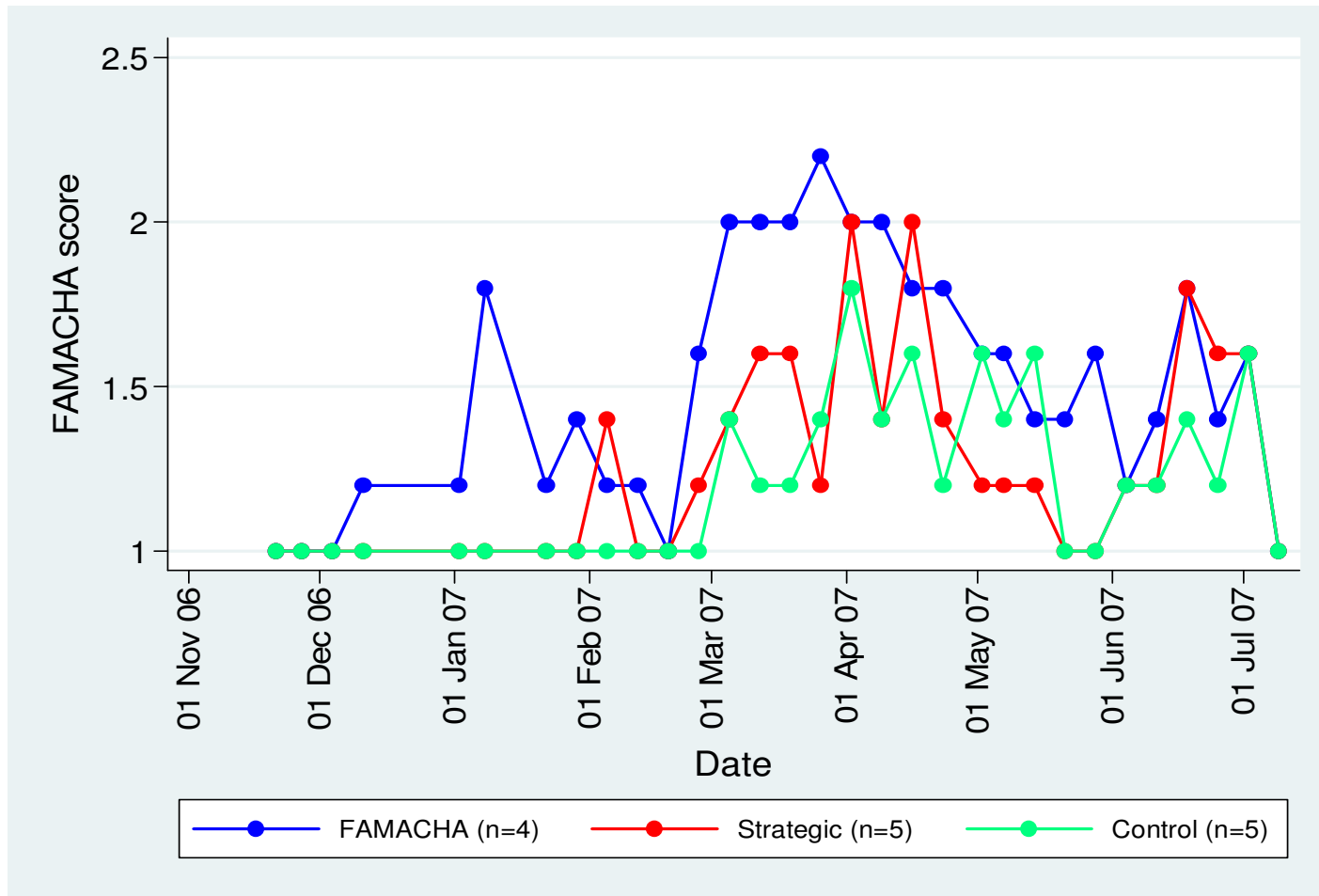
Note: Control = SUPPR group

Figure 4.4.4 Mean FAMACHA$^{©}$ scores for ewes born in August 2006 from start to end of trial period

Note: Control = SUPPR group

4.2 Lamb data

Lamb birth weights, weaning weights and number of days to weaning were recorded and ADG was calculated from weaning weights (less birthweights) and days to weaning and together with the birthweights was analysed (Tables 4.4.1 to 4.5.3). Lambs were weaned at approximately 25kg liveweight.

Lambing percentages were 71% for the FMCH group, 76% for the STRAT group and 64% for the SUPPR group (Cydectin group). Five ewes gave birth to twins. Of the ewes that gave birth to twins, one ewe was in the FMCH group, three ewes were from the STRAT group and one ewe was from the SUPPR group.

Unfortunately the farmer sold six lambs before weaning as they were considered to be "slow growers", of which four lambs were from the FMCH group (all singletons). One of the lambs was from the STRAT group and was one of a twin. The last lamb was from the SUPPR group and was also one of a twin.

Although the FMCH group had a high lambing percentage, the weaning percentage was poor. The FMCH group weaning percentage was 54%, the STRAT group weaning percentage was 72% and the SUPPR group was 52%.

When the "slow growers" are excluded from the data, Tables 4.4.1 and 4.4.2 show that there is no significant difference in the mean weight born per ewe (Figure 4.4.3).

Lamb birth weights were analysed excluding the "slow growers" and no significant difference in liveweight born per ewe was found in either the STRAT group (P=0.263) or the SUPPR group (P=0.900) as can be seen from Tables 4.4.1 to 4.4.3. Average daily gains (ADG) were calculated using the data collected by dividing the liveweight at weaning by the number of days to weaning and were analysed per ewe (Tables 4.5.1 and 4.5.2).

There was no significant difference in the results obtained (Table 4.5.3) for the STRAT group (P=0.661) or the SUPPR group (P=0.606). This may be due to the fact that the farmer sold lambs that were "slow growers". Had these lambs been included in the data, there may have been a significant difference between the FMCH lambs and those in the strategic and suppressive groups. Unfortunately no data was gathered on the lambs sold by the farmer and therefore analyses could not be performed.

4.3 Economics

Economic evaluation of the data initially appeared to show that there was a benefit to dosing more frequently. During the trial period the total cost of deworming the SUPPR group was R163.51 and the liveweight gain gave an additional income of approximately R2758.00 resulting in a financial gain of R2594.49 for 25 ewes when compared to the FMCH group. The cost of deworming the STRAT group for the trial period was R 104.65 and the liveweight gain gave an additional income of approximately R2261 which resulted in a financial gain of R2156.35 for 25 ewes. The cost for deworming the FMCH group was R10.96 for the duration of the trial.

Table 4.4.1 Group mean weight of lambs born per ewe

Subgroup	Mean body weight gain (kg)		
Birth month and year (ewes)	FMCH (SD)	STRAT (SD)	SUPPR (SD)
August 2005	6.22 (1.92)	6.95 (1.63)	6.06 (1.65)
August 2005 (n)	n=9	n=9	n=9
April 2006	5.36 (0.48)	5.75 (0.76)	5.57 (0.54)
April 2006 (n)	n=7	n=6	n=7

Table 4.4.2 Mean weight of lambs born per ewe for all groups

FMCH (SD)	STRAT (SD)	SUPPR (SD)
5.84 (1.50)	6.47 (1.45)	5.84 (1.27)
n=16	n=15	n=16

Table 4.4.3 Multiple regression analysis of mean weight of lambs born per ewe

Group (n)	Coef. of variance	95% Confidence interval	P	Std. Err.
STRAT (15)	0.54	-0.423 – 1.507	0.263	0.48
SUPPR (16)	0.06	-0.894 – 1.013	0.900	0.47

Table 4.5.1 Average Daily Gains of lambs born

Subgroup	Mean body weight gain (kg)		
Birth month and year (ewes)	FMCH (SD)	STRAT (SD)	SUPPR (SD)
August 2005	0.31 (0.07)	0.32 (0.12)	0.31 (0.02)
August 2005 (n)	n=7	n=9	n=7
April 2006	0.24 (0.04)	0.25 (0.04)	0.25 (0.04)
April 2006 (n)	n=5	n=6	n=7

Table 4.5.2 Average Daily Gains of lambs born for all groups

FMCH (SD)	STRAT (SD)	SUPPR (SD)
0.28 (0.07)	0.30 (0.10)	0.28 (0.04)
n=12	n=15	n=14

Table 4.5.3 Multiple regression analysis of Average Daily Gains of lambs born

Group (n)	Coef. of variance	95% Confidence interval	P	Std. Err.
STRAT (15)	0.01	-0.037 – 0.058	0.661	0.02
SUPPR (14)	0.01	-0.062 – 0.037	0.606	0.02

CHAPTER 5
DISCUSSION

From the FECs performed before and during the trial, it can be assumed that other sheep in the flock that were not involved in the trial, but which were also evaluated according to the FAMACHA$^©$ system, would have exhibited similar results (showing both resistance and resilience). A large proportion of the total flock was therefore untreated at each examination. Thus sufficient parasites were being excreted onto the pasture in order for the groups to have a significant challenge and for the trial to be a good study on the effects of deworming schedules.

Upon initial analysis, it appeared as though the FMCH group gained, on average, 3-4 kg less (P<0.05) than the STRAT and SUPPR groups when mean BW gains were compared for the entire trial period. This could be interpreted as indicating that a worm burden, that may not be apparent from the FAMACHA$^©$ scores as applied in this trial, can lead to a reduction in weight gain. However, the FAMACHA$^©$ system was very conservatively applied, since only categories were 4 and 5 were treated in this trial while current recommendations are based on treating most or all category 3 sheep as well, depending on the degree of anticipated worm challenge. This could have contributed to a poorer performance in this group. In addition, a food shortage occurred during the trial period and this must have exacerbated the situation.

The FMCH group initially had lower body weight gains but at lambing had undergone compensatory growth. Therefore the difference in BW gains in the multiparous ewes (Figure 4.1.1) can be attributed to growth of the conceptus (uterus, fluids and foetus) rather than parasitism or the control method used, since once all pregnant ewes were excluded and the data analysed again, there was no statistically significant difference in body weight gains between the FMCH, STRAT and SUPPR groups.

The partial correlation between BCS and mean BW indicated a highly significant negative correlation which indicates an increase in BW took place together with a

decrease in BCS. The only possible explanation for this phenomenon is foetal growth as normally one would expect to find a positive correlation between BCS and BW.

It can be deduced from Figure 4.4.1 that the FMCH group was most affected by poor nutrition as it did not benefit from regular dosing and thus the FAMACHA$^{©}$ scores were worse than in the STRAT or SUPPR groups, although these score were still acceptable and had not reached a mean score of 3. However, once supplementation was given the FAMACHA$^{©}$ scores improved and by the end of the trial period there was no significant difference in the three groups (as was the case for BCS).\

A partial correlation analysis of BCS and FAMACHA$^{©}$ scores showed a highly significant negative correlation. This can be expected, since FAMACHA$^{©}$ scores increase in value from 1 to 5 as the animal becomes more anaemic (Fig. 7.1), while BCS values estimates increase in value from 1 to 5 as the animal becomes fatter (Fig. 7.2). If this is borne in mind, then it can be interpreted as a highly significant correlation between worsening FAMACHA$^{©}$ and worsening BCS values and vice versa. This suggests that the food shortage leading to the decline in BCS may also have had an impact on the FAMACHA$^{©}$ scores, either by a decrease in available protein for the ewes, or a decrease in resilience to the *H. contortus* burden.

A highly significant positive correlation between BW and FAMACHA$^{©}$ scores can also be explained by this reasoning.

Therefore it can be concluded that the FAMACHA$^{©}$ system will not work as well when nutrition is poor compared with its application when nutrition is of high quality and quantity.

During the period of the trial, there was a food shortage caused by heavy, late season downpours, as can be seen in Figures 7.4.1, 7.4.2 and 7.4.3, which prevented the full use of the planted pastures for either grazing or harvesting for hay. Additional supplementary feed was supplied only once a substantial fall in BCS had occurred, and this could have

negatively affected both lambing and weaning percentages. This interpretation is supported by the fact that even though the FMCH group had the highest number (four) of lambs sold as "slow growers", all of these lambs were singletons. The ewe from the FMCH group that had twins was able to successfully raise both lambs, whereas the other two lambs that were sold as "slow growers" were one of a twin from both the STRAT and SUPPR groups. However, had the slow growers been included in the data, the FMCH group of ewes would have had a higher mean birth weight for the lambs but would have had a poorer performance with regards to ADG than the SUPPR and STRAT groups.

There are also financial and other implications that need consideration when farmers choose a deworming strategy. For instance, blanket treatments at the frequency applied in this trial are not sustainable as regards anthelmintic resistance. The rise of MAR strains of nematodes will force farmers who use frequent blanket treatments to face the reality that soon the currently available drug groups will no longer be effective. Even with new drug groups being introduced to the market, it is unwise and unsustainable to advocate frequent blanket treatments of entire flocks.

Economic calculations initially appeared to show a benefit by deworming on a regular basis, however, calculations were based on both pregnant and non-pregnant ewe data combined and therefore do not reflect the true cost and return for the farmer had the pregnant ewes data not been analysed together with those that did not fall pregnant during the trial. Once the pregnant ewes were separated from the rest, there was no significant difference between the three groups regarding liveweight gain. Therefore there was no financial benefit to the farmer in deworming either suppresively or strategically and in fact resulted in an economic loss due to the cost of anthelmintic when compared to using the FAMACHA$^{©}$ system.

Insufficient wool samples and a lack of representative samples (those samples taken by the farmer were too few to be considered representative samples) meant that the wool could not be analysed. Therefore, wool production was neither measured nor analysed in

this trial. Some work has been done on wool production by Eady *et al* (1998) where wool growth rates were correlated to parasite resistance. It was found that wool growth rate decreased in resistant sheep, however, Morris *et al* (2000) found no negative effect on wool growth rates. It would have been useful for this trial to see whether wool production was correlated to BCS as this could have provided additional evidence that poor nutrition during the winter months was responsible for the poor lambing and weaning percentages in all groups as well as the poor BCS (Figures 4.3.1 to 4.3.4).

It may appear from Figures 4.3.1 to 4.4.4 that there are at times important differences between groups in FAMACHA$^{©}$ and BCS averages but it must be borne in mind that these are subjective readings according to a 5 point scale and are not absolute measurements on a continuous scale.

Waller (1997) stated the central issue best and is quoted here: "Significant benefits are likely to emerge from research into non-chemotherapeutic approaches to nematode parasite control, such as grazing management, worm vaccines, breed selection and biological control. However, it is likely that none, in isolation or collectively, will completely replace the need for effective anthelmintics. What is needed is the integration of all methods of parasite control as they come to hand, with the underlying aim of reducing the use and thus preserving the effectiveness of anthelmintics."

Conclusion and recommendations

The importance of the FAMACHA$^{©}$ system has been comprehensively reviewed (Van Wyk and Bath, 2002; Kaplan *et al*., 2004; Bath *et al*., 2005; Van Wyk 2005, 2008; Kenyon *et al*, 2009) and has not only been tested in Southern Africa (Bath *et al*., 2001; Malan *et al*., 2001; Vatta *et al*, 2002) but also in North America (Kaplan *et al*., 2004), South America (Sotomaior *et al*., 2003, Molento *et al*., 2004; Vieira *et al*., 2008), the Caribbean (Mahieu *et al*., 2007), and Europe (Cabaret, 2004). Time and again it has proven to be an effective way of assessing whether or not animals are able to cope

unaided with high levels of worm challenge. In this study where Mutton Merino ewes on a semi-intensive farming system in a summer rainfall area were studied, there were no significant differences when using the FAMACHA$^{©}$ system compared to strategic dosing and suppressive dosing when the data was properly segregated by reproductive stage. The second and third options (STRAT and SUPPR) are not sustainable and will hasten the worldwide increase AR and MAR. By leaving the sheep or goats that appear to be coping with the worm burden untreated, anthelmintic use can be decreased to avoid serious resistance to the anthelmintics being used on a particular farm, and will not impose unacceptable limitations on the production parameters measured in this trial. This can be readily extrapolated to an insignificant effect on economic performance.

This study has demonstrated that:

1) There is no statistically significant difference in the production parameters measured when using the FAMACHA$^{©}$ system compared to either strategic or suppressive deworming.

2) Growth of the conceptus is probably responsible for the initial perception that weight gains may be significantly affected by using the FAMACHA$^{©}$ system. Stage of gestation should be considered in any future research.

3) The FAMACHA$^{©}$ system is an effective and economically beneficial method of managing *H. contortus* in sheep flocks on intensive farming systems in summer rainfall areas.

CHAPTER 6
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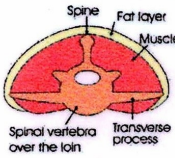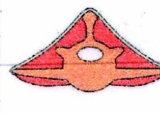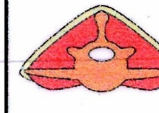
CHAPTER 7

ADDENDA

Figure 7.1 FAMACHA© card

Condition Scoring in Sheep

Spines	Individually clearly felt, sharp, obvious	Form a smooth line with deep undulations	Only slightly detectable undulations	Only detectable with firm pressure	Not detectable
Transverse processes	Fingers easily pass underneath	Smooth round edges	Well covered. Have to push firmly to get fingers underneath	Cannot be felt at all	
Muscle	Very little. Concave	Concave	Not concave. Not convex	Maximally developed. Convex	
Fat layer	No	Very thin	Moderate	Thick	Very thick to form a dip along top midline
Condition score	1	2	3	4	5

Description:
- The condition scoring is performed over the lower back area.
- Cases which do not fit these categories properly ie. fall between whole numbers, can be assigned half scores eg. 1.5, 2.5 etc.
- This scheme may be used in goats, but half a score is added to the score, since goats preferentially store fat intro-abdominally and not over the lower back.
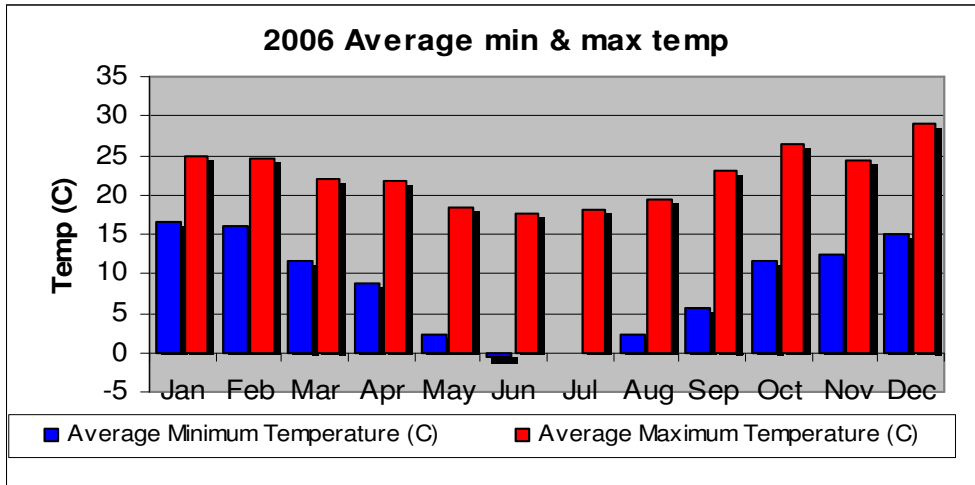
Figure 7.2 Body condition scoring card

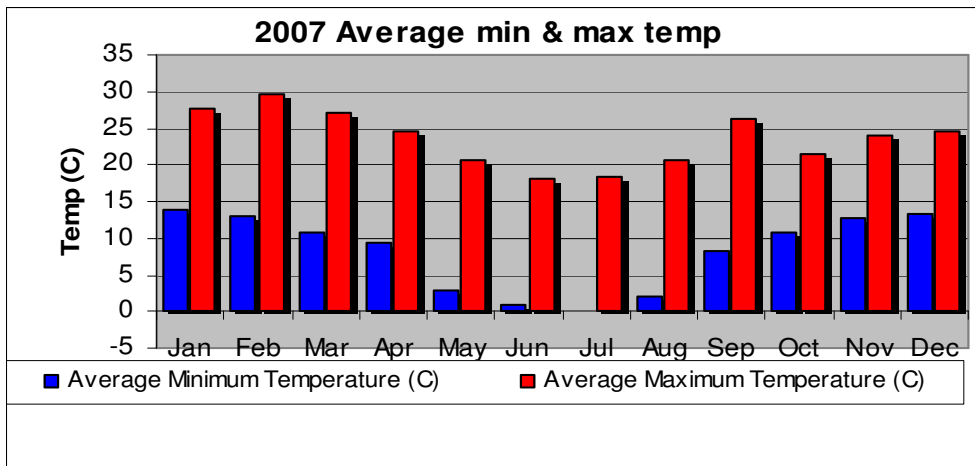**Figure 7.3.1 Average minimum and maximum temperatures in Delmas for 2006**

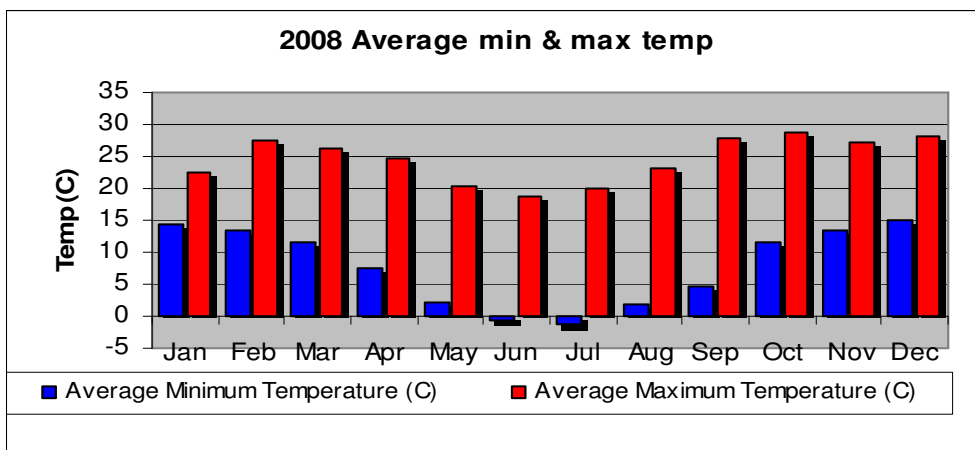**Figure 7.3.2 Average minimum and maximum temperatures in Delmas for 2007**

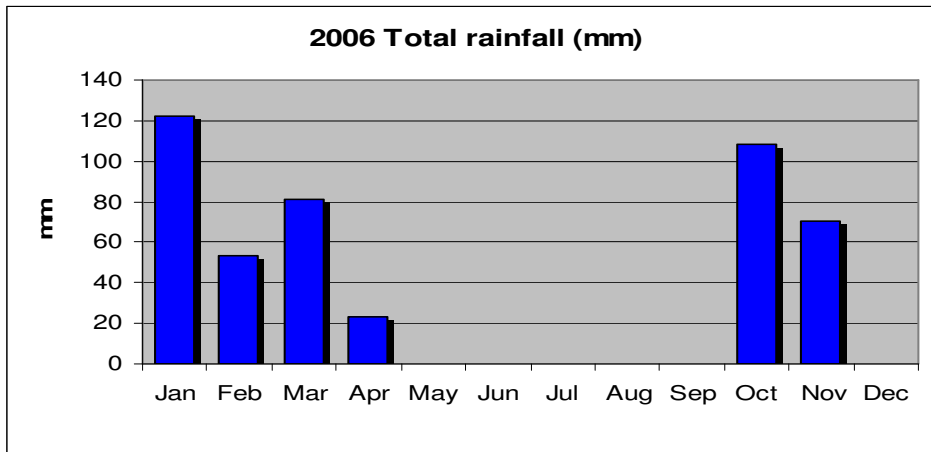**Figure 7.3.3 Average minimum and maximum temperatures in Delmas for 2008**

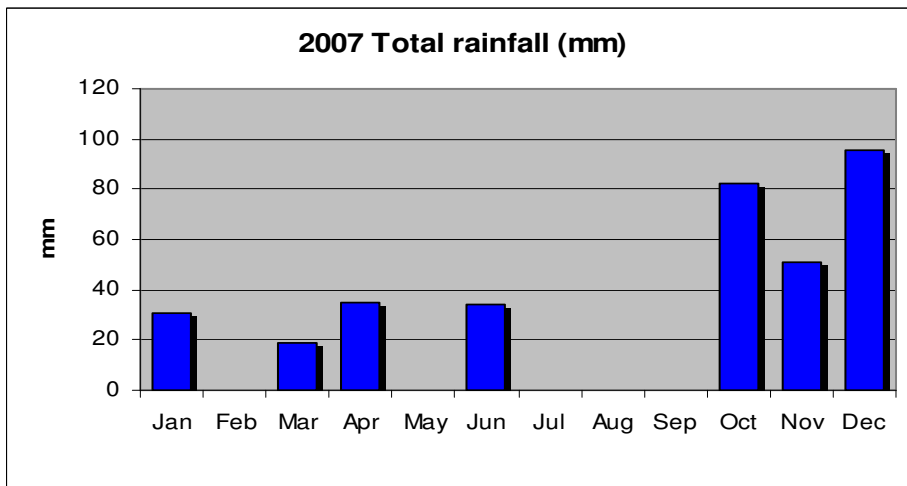**Figure 7.4.1 Total monthly rainfall in the Delmas area for 2006**

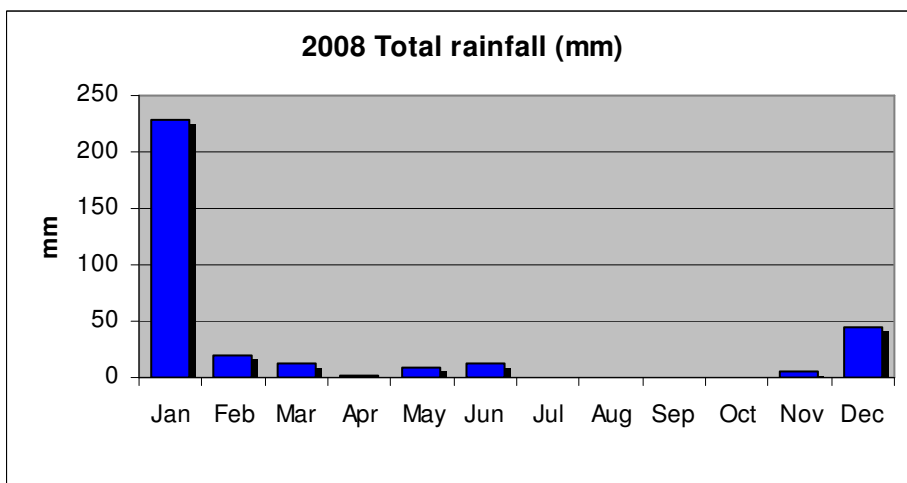**Figure 7.4.2 Total monthly rainfall in the Delmas area for 2007**

Figure 7.4.3 Total monthly rainfall in the Delmas area for 2008

Table 7.1 Summary of groups

Groups	Initial group composition (n)*			Ewes that lambed (n)
STRAT	Age group	1	10	5
		2	10	6
		3	5	0
SUPPR	Age group	1	10	5
		2	10	7
		3	5	0
FMCH	Age group	1	10	6
		2	10	7
		3	5	0

* Age group 1 = ewes born in August 2005
* Age group 2 = ewes born in April 2006
* Age group 3 = ewes born in August 2006

Table 7.2 Summary of initial analysis affecting costs and income

	FMCH	STRAT	SUPPR
Cost of deworming (R)*	10.96	104.65	163.51
Income (R)*	163.51	2261.00	2758.00
Number of lambs born (n)	16	15	16
Number of lambs weaned**(n)	12	15	14
Mean weight of lambs born (kg)	5.84	6.47	5.84
Mean ADG of lambs born (kg)**	0.28	0.30	0.28

* These costs are for the entire trial period. The income is before the pregnant ewes were separated from the rest of the ewes and therefore is not a true reflection as once ewes were separated there was no significant difference between weight gains and thus potential income.
** These figures are due to the farmer selling "slow growers" and not due to mortalities. This affected the results for the ADG.