Trop Anim Health Prod (2010) 42:961–968
DOI 10.1007/s11250-009-9514-5

The effect of dietary garlic supplementation on body weight gain, feed intake, feed conversion efficiency, faecal score, faecal coliform count and feeding cost in crossbred dairy calves

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Accepted: 20 November 2009 / Published online: 9 December 2009

Abstract Thirty-six crossbred calves (Holstein cross) of 5 days of age were used to study the effect of garlic extract feeding on their performance up to the age of 2 months (pre-ruminant stage). They were randomly allotted into treatment and control groups (18 numbers in each group). Performance was evaluated by measuring average body weight (BW) gain, feed intake (dry matter (DM), total digestible nutrient (TDN) and crude protein (CP)), feed conversion efficiency (FCE; DM, TDN and CP), faecal score, faecal coliform count and feeding cost. Diets were the same for the both groups. In addition, treatment group received garlic extract supplementation at 250 mg/kg BW per day per calf. Body weight measured weekly, feed intake measured twice daily, proximate analysis of feeds and fodders analysed weekly, faecal scores monitored daily and faecal coliform count done weekly. There was significant increase in average body weight gain, feed intake and FCE and significant decrease in severity of scours as measured by faecal score and faecal coliform count in the treatment group compared to the control group ($P<0.01$). Feed cost per kilogramme BW gain was significantly lower in the treatment group compared to control group ($P<0.01$). The results suggest that garlic extract can be supplemented to the calves for better performance.

Keywords Calf · Pre-ruminant · Garlic extract · Body weight gain · Faecal score · Faecal coliform count

Introduction

Calves are the future replacement stocks for cows and bulls. Calves are often underestimated and neglected because they need financial investment and do not bring any immediate return. But serious attention should be given to calf rearing because initial growth of an animal is the most important phase of its life and it has immense bearing on the early maturity and production; initial body weight has been found to be correlated with later body weight and the growth rates at any stage of development can also be taken as an aid to selection. Further, the sexual maturity depends on bodyweight mainly rather than age (Ghose et al. 1979). Therefore, attainment of optimum body weight at an early age is very important.

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Many substances have been supplemented in calf diet to get the desired result, and a recent development is the use of herbs. Beneficial effects of herbs or botanicals in farm animals may arise from the activation of feed intake and the secretion of digestive secretions, immune stimulation, anti-bacterial, coccidiostatic, anthelmintic, antiviral or anti-inflammatory activity and inhibition or particularly, antioxidant properties. Most of these active secondary plant metabolites belong to the classes of isoprene derivatives, flavonoides and glucosinolates, and a large number of these compounds have been suggested to act as antibiotics or as antioxidants in vivo as well as in food. Herbs or the phytochemicals can influence selectively the microorganisms by an anti-microbial activity or by a favourable stimulation of the eubiosis of the microflora. Herbs can also contribute to the nutrient requirements of the animals, stimulate the endocrine system and intermediate nutrient metabolism (Wenk 2003).

Garlic supplementation through feed, in particular, has many favourable experimental and clinical effects, which include stimulation of immune function, enhanced foreign compound detoxification, restoration of physical strength and resistance to various stresses (Amagase et al. 2001). The primary sulphur containing constituents in whole intact garlic are the γ-glutamyl-S-alk(en)yl-L-cysteines and S-alk(en)yl-L-cysteine sulfoxides, including alliin. The γ-glutamyl peptides are biosynthetic intermediates for corresponding cysteine sulfoxides (Lancaster and Shaw 1989). During storage of garlic bulbs at cool temperatures, allin accumulates naturally. On average, a garlic bulb contains up to 0.9% γ-glutamylcysteines and up to 1.8% allin. In addition to these sulphur-containing compounds, intact garlic bulbs also contain small amount of S-allyl cysteine (SAC), but no allicin. SAC is formed from γ-glutamyl cysteine catabolism and has been reported to contribute to the health benefits of garlic. Once garlic is processed by cutting or crushing, compounds in the intact garlic are converted into hundreds of organosulphur compounds in a short period of time. When garlic is 'damaged', i.e., attacked by a microbe, crushed, cut or chewed, or when it is dehydrated, pulverized and then exposed to water, the vacuolar enzyme, allinase, rapidly lyses the cytosolic cysteine sulfoxides (allin) to form cytotoxic and odiferous alkyl alkane-thiosulfinates such as allicin. Allicin and other thiosulfinates instantly decompose to other compounds, such as diallyl sulphide, diallyl disulfide (DADS) and diallyl trisulfide, dithiins and ajoene (Amagase et al. 2001). Additional constituents of intact garlic include steroidal glycosides (Matsuura et al. 1988), lectins (Kaku et al. 1992), prostaglandins, fructan, pectin, essential oil, adenosine, vitamins B-1, B-2, B-6, C and E, biotin, nicotinic acid, fatty acids, glycolipids, phospholipids, anthocyanins, flavonoids, phenolics and essential amino acids (Fenwick and Hanley 1985).

The anti-bacterial activity of thiosulfinates, including allicin, has been explained as a reaction between thiosulfinates and SH groups of essential cellular proteins (Small et al. 1947, 1949). The well-established anti-microbial actions and chemical complexity of garlic materials and their broad-spectrum effectiveness suggest that acquired antibiotic resistance would be unlikely (O'Gara et al. 2000). In addition, direct intragastric effects are feasible because garlic antimicrobials are unaffected by acid environments (Lawson 1996) and because gastric juice enhances the anti-microbial activity of garlic constituents (Fortunatov 1955). The traditional use of dietary garlic to fight infections and its medicinal use to combat various diseases (Reuter et al. 1996) suggest that the systemic distribution of garlic materials is efficient (O'Gara et al. 2000). Garlic sulphides are readily absorbed (Koch 1996); some, such as DADS, have significant half-lives in blood, and the major metabolite of allicin derivatives, allyl methyl sulphide (Lawson 1998), is relatively persistent, as it is excreted on breath. Thus, an anti-microbial effect of circulating garlic materials against microbes colonising, the gastric mucosa is feasible (O'Gara et al. 2000). So there is greatly renewed interest in developing natural supplements like garlic extract to maintain both animal performance and welfare.

Keeping in view the various reports, the objective of the current experiment was conducted on crossbred calves at their pre-ruminant stage to see the effects of feeding garlic extract on their performance (body weight gain, feed intake, feed conversion efficiency, faecal score and faecal coliform count) and feed cost of rearing.

Materials and methods

The study was conducted at Dairy Cattle Farm of National Dairy Research Institute, Karnal, Haryana, India from September to November 2007. A total of 36 newborn crossbred (Holstein cross) calves (5 days old) were randomly allotted equally into two groups and calves were maintained up to 2 months of age (pre-ruminant stage). Weaning of the calves was done just after birth. Treatment group was supplemented with garlic extract 250 mg/kg BW per day per calf, which was mixed with the milk once in the morning, whereas, control group did not receive any such supplementation.

Housing of animals

The calves were housed in individual pens in a naturally ventilated barn with open area in one side containing water trough. The shed was provided with concrete flooring, covered partly by asbestos roof and partly open for loafing. Water trough and feeding trough were provided within the shed. Each calf shed was washed with water and disinfectant solution every day.

Diets and feeding

The calves were taken from the institute herd at 5 days old after colostrum feeding was over. The feeding of milk was carried out twice a day. Special care was taken to keep the milk temperature close to the body temperature. The feeding schedule followed during the experiment is as follows: whole milk fed to the calves at the rate of 1/10th of BW up to 3rd week, 1/15th of BW up to 7th week and 1/25th of BW in the 8th week of study; skim milk fed to calves at the 1/25th of BW from 4th to 7th week and then 1/15th of BW on 8th week of study; concentrate fed at the rate of 120 g/calf/day from 4th week to 7th week and 250 g/calf/day at 8th week of study. Green fodder (oat; *Avena sativa*) was supplied at the rate of 700, 750, 850, 1,000 and 1,100 g per calf per day at 4th, 5th, 6th, 7th and 8th week of study, respectively. The concentrate (calf starter) contained following ingredients (percent): maize—35, groundnut cake—10, gram—33, wheat bran—20, mineral mixture—3 and multi-vitamins-20 g/100 kg.

Garlic extract supplementation

The calves of the treatment group were supplemented with 250 mg/kg BW per day per calf garlic extract from 5 days to 2 months of age (pre-ruminant stage).

Preparation of garlic extract Garlic bulbs were purchased from local market of Karnal and stored at 4°C. Garlic bulbs were weighed then sterilised in distilled water was added in the ratio of 1:2 weight/volume. Then paste was formed in an electrical mixer. Then filtered through muslin cloth and the filtered liquid was taken for use.

Data recorded

BW was recorded at weekly interval in morning hours before morning feeding. Feed intake (whole milk, skim milk, concentrate and green fodder) was measured twice daily. Proximate composition of feeds and fodder was analysed at weekly interval (AOAC 1990). Feed conversion efficiency (FCE) was calculated as under:

$$\mathrm{DM(dry\ matter)intake/kg\ gain\ in\ BW} = \frac{\mathrm{DM\ consumed(Kg/day)}}{\mathrm{Daily\ BW\ gain(kg)}}$$
$$\mathrm{TDN(total\ digestible\ nutrient)intake/kg\ gain\ in\ BW} = \frac{\mathrm{TDN\ consumed(Kg/day)}}{\mathrm{Daily\ BW\ gain(kg)}}$$
$$\mathrm{CP(crude\ protein)intake/kg\ gain\ in\ BW} = \frac{\mathrm{CP\ consumed(Kg/day)}}{\mathrm{Daily\ BW\ gain(kg)}}$$

Faecal scores based on a four-point scale were recorded daily (Larson et al. 1977). Scores were established as: (1) normal—firm but not hard, (2) soft—does not hold firm, (3) runny—spreads easily, and (4) devoid of solid matter. Feed cost of rearing per calf per day based on current market rate (Table 1) was calculated by multiplying feed consumed by a calf per day with cost of each feed items (whole milk, skim milk, concentrate mixture and green fodder) including garlic. Feed cost per kilogramme gain in body weight was calculated by dividing feed cost per calf per day by body weight gain per calf per day.

Table 1 Composition of feed items on dry matter basis and their market rates at the time of study

Items	DM (g/kg)	CP (g/kg DM)	TDN (g/kg DM)	Cost (Rs.)/kg
Whole milk	142.7	31.2	160.5	13.00
Skim milk	95.7	26.7	91.4	9.00
Concentrate mix.	900.1	203.1	701.6	8.50
Green fodder (oat)	230.5	59.3	532.2	0.35
Garlic	–	–	–	70.00

DM dry matter, *TDN* total digestible nutrient, *CP* crude protein

Faecal coliform analysis Rectal faecal samples were collected at weekly interval. Sterile gloves were used to obtain 3 to 5 g of faeces following peri-anal cleansing with dilute Betadine solution. The sample was placed in a sterile disposable petridish, refrigerated and transferred within 30 min to the laboratory for coliform investigation. For determination of coliform counts, 1 g samples were diluted in 99 ml sterile phosphate buffered saline (pH 7.2) and mixed for 5 min with a magnetic stirrer. Serial dilutions up to 1:10^6 were prepared from this mixture. Each dilution was plated on Violet Red Bile Agar media (Himedia) and incubated for 24 h at 35°C (FDA 1998). The numbers of organisms were expressed as $\log_{10}$ colony forming units (CFU) per gramme of faeces.

Statistical analysis

Data for BW gain, feed intake (dry matter (DM), crude protein (CP), total digestible nutrient (TDN)), feed conversion efficiency (DM, CP, TDN), faecal score, faecal coliform count, feed cost per calf per day and feed cost per kilogramme body weight gain were analysed by standard procedures of analysis of variance to ascertain whether significant differences in those measurements in each of the trials were caused by the garlic extract supplementation.

Results

Body weight gain

There was significant difference in body weight gain per calf per day between treatment and control groups ($P< 0.01$; Table 2). The body weight gain per calf per day in treatment group was 44.05% higher than control group.

Feed intake

The mean total DM, TDN and CP intake per calf per day significantly ($P<0.01$) differed between treatment and control groups (Table 2). The mean DMI per calf per day, TDN intake per calf per day and mean CP intake per calf per day in the treatment group were 12.44%, 11.46% and 12.42% higher than control group, respectively.

Feed conversion efficiency

There was significant ($P<0.01$) difference of FCE of DM, FCE of TDN and FCE of CP intake between

Table 2 Least square means of performance of calves supplemented with Garlic Extract

	Control	Treatment
BW gain per calf per day (g)	262.74^a±14.78	378.47^b±13.69
Feed intake per calf per day (g)		
DM	649.14^a±17.18	729.89^b±18.78
TDN	170.44^a±7.58	189.98^b±7.84
CP	33.08^a±1.48	37.19^b±1.56
Feed conversion efficiency (feed intake, BW gain; kg/kg)		
FCE of DM	5.545^a±0.682	2.463^b±0.646
FCE of TDN	1.366^a±0.136	0.617^b±0.129
FCE of CP	0.265^a±0.026	0.121^b±0.025
Faecal score (scale 1 to 4)	2.062^a±0.046	1.239^b±0.051
Faecal coliform count (log CFU^6 per gramme faeces)	8.436^a±0.715	5.039^b±0.633
Feed cost (Rs.) per calf per day	45.74^a±0.49	51.89^b±0.46
Feed cost (Rs.) per kilogramme gain in BW	231.01^a±21.87	161.61^b±15.86

^{a,b} Means within a row with different superscripts differ significantly ($P<0.01$)

BW body weight, *DM* dry matter, *TDN* total digestible nutrient, *CP* crude protein, *FCE* feed conversion efficiency, *CFU* colony forming unit treatment and control groups (Table 2). The treatment group was found to be 125.08%, 121.21% and 118.86% efficient than control group in FCE of DM, FCE of TDN and FCE of CP intake, respectively.

Faecal score

The mean faecal score differed significantly between treatment and control groups ($P<0.01$; Table 2). Lower faecal score was observed in treatment group compared to control group.

Faecal coliform count

The mean faecal coliform count (log CFU per gramme faeces) was significantly lower in the treatment group than control group ($P<0.01$; Table 2). Treatment group had 67.41% lower faecal coliform count than control group.

Feed cost per calf per day and feed cost per kilogramme gain in body weight

The mean feed cost (Rs.) per calf per day in treatment and control groups were 51.89±0.46 and 45.74±0.49, respectively (Table 2) and they differ significantly ($P<$ 0.01). The feed cost per calf per day in the treatment group was 13.45% higher compared to control group.

The mean feed cost (Rs.) per kilogramme body weight gain in treatment and control groups were 161.61±15.86 and 231.01±21.87, respectively (Table 2) and they differ significantly ($P<0.01$). The feed cost per kilogramme body weight gain was 42.94% lower in the treatment group compared to the control group.

Discussion

This study was performed to observe the effect of garlic extract on the performance of calves. The improved body weight gain, feed intake and FCE were found in this study. This may result from improved enteric health, which is due to the antimicrobial action of garlic. It is possible that diets containing garlic extracts exert a positive effect on the balance of gut microbial populations (Lewis et al. 2003), which may be responsible for this positive result. Supplementation of garlic extract resulted in proper maintenance of liver function because it has an important protective role against liver toxicity caused by a variety of medicinal and environmental substances (Borek 2001). Further, garlic enhances the activity of pancreatic lipase and amylase, and this positive influence on the activity of enzymes may have a supplementary role in the overall digestive stimulant action, besides causing an enhancement of the titres of digestive enzymes in pancreatic tissue (Rao et al. 2003). Antioxidants in garlic extract, such as the organosulfur compounds, protect against oxidative damage, thus, lower the risk of injury to vital molecules and may help prevent the onset and progression of disease (Gutteridge 1993; Borek 1997). Garlic exerts antioxidant action by scavenging reactive oxygen species, enhancing the cellular antioxidant enzymes, such as superoxide dismutase, catalase and glutathione peroxidase and increasing glutathione in the cells (Borek 2001) .Further feeding garlic resulted in the reduction in crypt depth in the ileum (Demir et al. 2003), which results in better absorption of nutrients and thereby, better growth, feed intake and FCE. All these factors may be responsible for better growth and well being of calves. Garlic supplementation resulted in significant increase in feed consumption in piglets (Krusinski 2004; Kleczkowski et al. 2004) and improved body weight gain in piglets (Kleczkowski et al. 2004; Krusinski 2004; Grela and Klebaniuk 2007; Tatara et al. 2008), grower–finisher pigs (Onibala et al. 2001; Grela et al. 2007) and lambs (Badias and Yaniz 2004). In rabbit, feeding dried garlic for 8 weeks resulted in significant improvement in body weight, daily live weight gain (El-Walfa et al. 2002). However, Lovatto et al. (2005) reported that there was no differences in body weight gain between piglets fed diets with or without garlic, which might be due to lower feed consumption in the garlic fed group. Garlic feeding resulted in increase feed conversion efficiency in piglets (Krusinski 2004), grower–finisher pigs (Onibala et al. 2001, Grela et al. 2007) and in rabbit (El-Walfa et al. 2002). Ahmed et al. (2009) reported that addition of 2.5% natural juice containing garlic significantly increased daily gain of the growing buffalo calves compared with the control group but did not significantly affect the feed consumption as DM, TDN or CP compared with the control. Ahmed et al. (2009) also reported better feed conversion of the treatment group than the control but the difference was not significant. Czech et al. (2009) reported significant higher daily gain and better feed conversion efficiency in the growing–finishing pigs supplemented with herbal mixture containing garlic than the control group.

Lower faecal score and lower faecal coliform count in the treatment group is due to the anti-microbial properties of garlic. The general reaction as proposed by Small et al. (1947),

$$R\text{-}\overset{\overset{O}{\uparrow}}{S}\text{-}S\text{-}R' + HS\text{-}R'' \rightarrow R'\text{-}S\text{-}S\text{-}R'' + RSOH$$

is the common mechanism of anti-bacterial activity of thiosulfinates where thiosulfinates react with biological molecules having free SH groups to influence or inhibit growth of bacteria. The breakdown products of allicin have the ability to cross cell membranes and combine with sulphur containing molecular groups in amino acids and proteins including bacterial enzymes, thus, interfering with bacterial cell metabolism. Animal cells contain glutathione, a sulphur containing amino acid that combines with the allicin derivative and therefore, are not poisoned by allicin derivatives, thus, preventing cell damage (Kyung et al. 2002; Davis 2005).The anti-bacterial properties of garlic were confirmed against *Escherichia coli* (Hughes and Lawson 1991; Ahmed et al. 2009), *Staplylococcus aureus* (Hughes and Lawson 1991) and *Salmonella* spp. (Ahmed et al. 2009). Ahmed et al. (2009) reported, although lower faecal coliform count was found in the treatment group supplemented with natural juice containing garlic in growing buffalo calves than the control, but there was no significant difference between the two groups. However, laboratory studies also indicated that garlic extract had significant inhibitory effect on coliform (Leuschner and Zamparini 2002; Nikolic et al. 2004). MeiChin et al. (2002) reported that garlic extract have potential for prevention or control of infections caused by enteric pathogens, such as *E. coli*, *Enterobacter cloacae*, *Enterococcus faecalis* and *Citrobacter freundii.* El-Astal (2004) reported high anti-bacterial efficacy of garlic extract on certain pathogenic gram-positive bacteria (*Staph. aureus*, *Staph. saprophyticus*, *Strept. pneumonia* and *Strept. faecalis*) and gram-negative bacteria (*E. coli*, *E. cloacae, Klebsiella pneumonia*, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Acinetobacter haemolyticus*). However, lactic acid bacteria (beneficial) are the least sensitive microorganisms to the inhibitory effects of garlic (Rees et al. 1993).

Feed cost is the major component of calf rearing. Higher body weight gain and feed intake was found in the treatment group throughout the experimental period. The higher feed cost in the treatment group was due to more feed intake but the feed cost per kilogramme BW gain was lower in the treatment group due to higher FCE compared to control. No such report has been traced out regarding feed cost of calves supplemented with garlic extract to compare this result.

In conclusion, garlic extract supplementation in the calf's diet significantly improved their growth and other performances at their pre-ruminant stage. Therefore, significant lower feed cost per kilogramme BW gain was found in the treatment group. The result suggests that garlic extract can be used in the calf's diet for better growth and performance. Moreover use of garlic extract as feed supplement seems to be practically feasible and could be easily prepared and adopted by the farmers at home. The farmers can prepare the garlic extract in their home by crushing garlic in pestle and mortar, adding water (in ratio of 1:2), then filtering in muslin cloth and finally feeding the calves by mixing in milk according to the body weight of the calves.

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