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Effect of zinc supplementation from organic and inorganic sources on performance, nutrient utilization and carcass characteristics in lambs

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ABSTRACT

An experiment was conducted on 42 male Nellore lambs to determine the effect of zinc level and source on performance, nutrient digestibility and carcass characteristics of lambs by randomly allotting them to 7 groups in completely randomized design. The dietary treatments were, viz. basal diet (no Zn supplementation, BD; 29.3ppm); other 6 groups were offered BD supplemented with 15, 30 or 45ppm Zn from Zn sulphate and Zn proteinate, respectively. The lambs were fed the respective diets at 3.5% body weight to meet nutrient requirements except Zn for 150 days including 6-day metabolic trial. The intake and digestibility of organic nutrients including fibre fractions, nitrogen and energy balances were similar among BD and Zn supplemented lambs at varying doses and sources. The dose and source of Zn had no effect on weight gains, nutrient intake and efficiency. The pre slaughter weight, hot carcass weight, dressing percentage, edible and non-edible proportion of carcass and yield of whole sale cuts were similar among the groups except for higher rack yield on 30 and 45ppm Zn supplementation. Meat yield was higher and fat yield was lower in $ZnSO_4$ fed lambs compared to Zn proteinate. The proportion of meat per unit of bone was higher in Zn supplemented lambs. The results indicated that 29.3ppm Zn in diets, meeting the NRC (1985) recommendations was sufficient for maximum performance and carcass traits in lambs. Dose and source of Zn supplementation influenced bone, meat and fat proportions in carcass.

Key words: Carcass, Lambs, Nutrient digestibility, Performance, Zinc levels, Zinc source

Zinc (Zn) is a constituent of several enzyme systems in the body supporting growth, reproduction and metabolism of nucleic acids, proteins and carbohydrates (Georgievskii 1982). Improvement in utilization of amino acids for protein synthesis with zinc supplementation was also reported (Spears 1989). Zinc is deficient in livestock feeding systems in many parts of our country and marginal zinc deficiency is a more widespread occurrence. The Zn supplementation above recommended levels in practical diets improved growth performance of buffalo calves (Daghash and Mousa 1999, Jadhav *et al*. 2008), heifers (Spears 1989) and steers (Spears and Kegley 2002). Organic sources of Zn as zinc methionine increased the growth performance and carcass traits of fattening cattle (Brethour 1984) and reported to be more bioavailable in ruminants (Spears 1989). Spears and Kegley (2002) reported heavier hot carcass weights and higher dressing percentages in steers fed Zn proteinate than control or supplementation as Zn oxide. So far research on this area is mostly restricted in beef cattle. Thus the present experiment was conducted in lambs to study the effect of Zn supplementation from organic and inorganic sources on their growth performance, nutrient utilization and carcass characteristics.

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MATERIALS AND METHODS

Animals, housing and feeding management: Healthy male lambs (42), about 9 months of age and uniform body weight (28.26±0.635 kg) were assigned randomly to 7 groups of 6 animals in each in a completely randomized design. All the animals were housed in a well-ventilated animal shed with the provision of individual feeding and watering. The lambs were dewormed before the start of the experiment and then at regular intervals during the experimental period of 150 days. Lambs were fed the respective diets at 3.5% of their body weight with 5% extra allowance, thrice a day. The feed to be offered was calculated at every fortnightly interval according to body weight changes. Clean drinking water was provided *ad lib.* twice a day.

Feeds: All the lambs were fed a common sorghum straw based basal diet (Table 1), except for the difference in level of Zn supplementation, which was 0, 15, 30 and 45ppm from inorganic and organic sources, viz. zinc sulphate and zinc proteinate, respectively. The basal diet met the nutrient requirements (ICAR 1998) of lambs except Zn. The estimated Zn content in the basal diet was 29.28ppm. The Zn content in $ZnSO_4$ and Zn proteinate in present study was 22 and 10%, respectively. The animals of group 1 (BD) were offered basal diet, group 2 (15–1) and 3 (15-O) were offered basal diet supplemented with 15 ppm Zn from inorganic and organic source, respectively, group 4 (30–1) and 5 (30-O) were fed basal diet supplemented with 30ppm Zn from $ZnSO_4$ and Zn proteinate and group 6 (45–1) and 7 (45-O) were offered basal diet supplemented with 45 ppm Zn from inorganic and organic source, respectively.

Body weights and feed efficiency: All lambs were weighed individually at every fortnight interval before feeding and watering for 2 consecutive days in the morning to assess body weight changes and the growth rate. Efficiency of nutrient utilization was calculated as unit intake per unit gain.

Nutrient utilization and balances: A 6-day metabolism trial after 120 days of experimental feeding was conducted to determine the nutrient digestibility and balances of nitrogen, energy and Zn in the animals. The metabolism trial involved daily recording of feeds offered and residues left and total excretions of faeces and urine after allowing for proper acclimatization of lambs in metabolic cages.

Carcass studies: Four representative lambs from each group were slaughtered at the end of 150 days of experimental feeding to assess the carcass characteristics. The preweighed lambs were fasted overnight with a free access to water and were slaughtered the next day by '*Halal*' method (Gracey 1981) after noting the overnight fasted weight. After skinning and evisceration, the weight of hot carcass was recorded. Weight recorded after deducting gut fill from pre-slaughter weight was noted as empty body weight. Carcass was divided into 5 major primal cuts namely leg, loin, rack, breast and fore shank and neck and shoulder. Each cut weight was recorded and expressed as percentage of carcass weight. The weight of hot carcass was expressed as percentage of pre-slaughter weight as well as empty body weight to arrive at dressing percentage. The weight of edibles (carcass, liver, heart, kidneys, testes, dressed head and feet) and inedibles (blood, empty gastrointestinal tract, skin, spleen and lungs with trachea) were recorded and expressed as percent of pre-slaughter weight. The separated bone, meat and fat of carcass of each animal were weighed and expressed as per centage of carcass weight.

Analytical procedure: Feed and faecal samples collected during metabolism trial were analysed for proximate constituents (AOAC 2000) and fibre fractions (Van Soest *et al*. 1991). The CP of the samples was determined by Kjeldahl's method using nitrogen analyzer. The fat was estimated using soxhtherm system. The crude fibre (CF) was estimated by fibre bag system. Gross energy (GE) in feed, faeces and urine samples were estimated by bomb calorimeter to arrive at the energy balance. The Zn content in feed, faeces and urine samples was estimated by atomic absorption spectrophotometer.

Statistical analysis: Data were analyzed by the GLM procedure of SPSS 10 (1997) with each lamb as replicate in a completely randomized design with Zn level and source of Zn supplementation as the 2 factors of variation. The means were compared using Duncan's multiple range test (Duncan's 1955).

RESULTS AND DISCUSSION

The BD contained 12.61% CP, 35.9% CF, 9.23% total ash, 43.1% neutral detergent fibre (NDF) and 22.8% acid detergent fibre (ADF). The Zn content in BD was 29.3ppm comparable to the recommended level of Zn (29–33ppm) for lambs (NRC 1985, ICAR 1998). Zn was supplemented to BD at 15, 30 and 45ppm and the amount of Zn estimated in diets (44.34, 59.55, 74.30ppm from inorganic and 45.12, 60.46 and 75.79ppm from organic sources, respectively) was similar to the calculated values.

Zn supplementation at either dose or from any source did not affect the daily dry matter (DM) intake and its digestibility (Table 2). Galyean (1996) reported higher DM intake (DMI) in Zn supplemented steers. Similar to present findings, Spears (1989), Kegley and Spears (1994), Engle *et al.* (1997) and Mandal (2004) found that dietary Zn supplementation at different levels ranging up to 200ppm, had no effect on the DMI of the animals. On other hand Malcolm-Callis *et al*. (2000) observed linear decrease in daily DMI with linear increase in Zn supplementation from 20 to 200ppm.

Like DM, digestibilities of organic matter (OM), ether extract (EE), CF, nitrogen free extract (NFE), GE, hemicellulose were also similar (P>0.05) among the Zn supplemented and BD fed lambs (Table 2). Supplementation of Zn at 15, 30 or 45ppm from inorganic or organic source had no affect on digestibility of proximate constituents, fibre

Table 1. Ingredient composition (kg/100kg) of basal diet

Ingredient	Proportion
Sorghum straw	40.0
Maize	40.0
Soybean meal	6.5
Urea	1.0
Red gram husk	1.5
Molasses	8.5
Salt	1.0
Limestone powder	1.01
Dicalcium phosphate	0.720
Trace mineral and vitamin mixture	0.055

Trace mineral and vitamin mixture provided (mg/kg diet): Iron, 30; manganese, 40; copper, 10; cobalt, 0.2; molybdenum, 0.5; iodine, 0.25; selenium, 0.2. vitamins A and E were provided to supply 940 IU and 210 IU per kg diet, respectively.

Table 2. Dry matter intake and nutrient digestibility in lambs and nutritive value of diets on to lambs fed diets varying in zinc concentration

Diet	DM intake (g)	Nutrient digestibility (%)											Nutritive value (%)		
		DM	OM	CP	EE	CF	NFE	GE	NDF	ADF	HC	DCP	TDN	DE (Mcal/kg)	ME (Mcal/kg)
BD	1211	60.63	62.27	59.67^{ab}	61.48^{ab}	61.37	62.65	66.43	44.74^{bc}	47.41^{ab}	28.27^{c}	7.52^{ab}	55.65	1.84	1.62
15–1	1270	58.29	60.63	53.70^{b}	57.28^{ab}	59.87	63.88	66.75	49.50^{ab}	44.44^{b}	56.32^{ab}	6.05^{d}	59.21	1.53	1.32
15–O	1298	60.28	61.34	65.89^{a}	50.13^{b}	57.59	60.57	67.53	46.37^{bc}	43.72^{b}	51.84^{ab}	8.43^{a}	56.64	1.71	1.50
30–1	1350	60.83	58.56	55.12^{b}	57.93^{ab}	59.52	61.56	65.15	39.83^{c}	41.48^{b}	51.24^{ab}	6.35^{cd}	56.52	1.63	1.40
30-O	1231	63.24	64.35	55.11^{b}	71.52^{a}	65.13	65.36	69.62	55.28^{a}	55.57^{a}	60.91^{a}	6.98^{bc}	56.16	1.70	1.48
45–1	1159	63.26	64.63	59.10^{ab}	62.12^{ab}	63.90	64.67	68.46	48.57^{abc}	50.80^{ab}	46.05^{ab}	7.60^{ab}	58.91	1.79	1.57
45-O	1179	62.99	65.11	60.21^{ab}	49.78^{b}	64.65	64.91	69.43	48.42^{abc}	45.77^{b}	42.39^{bc}	7.60^{ab}	60.30	1.66	1.44
P	0.541	0.667	0.220	0.028	0.030	0.175	0.155	0.341	0.019	0.043	0.001	0.001	0.990	0.169	0.112
BD vs Zn	0.643	0.663	0.938	0.623	0.571	0.870	0.688	0.411	0.339	0.905	0.008	0.436	0.640	0.059	0.048
Main factors															
Zn supplementation (ppm)															
0	1210	60.63	62.27	59.67	61.48	61.37	62.65	66.43	44.73	47.41	28.27^{b}	7.52	55.65	1.84	1.62
15	1284	59.29	60.98	59.79	53.70	58.73	62.22	67.14	47.94	44.08	54.08^{a}	7.24	57.93	1.62	1.41
30	1290	62.04	61.45	55.12	64.73	62.32	63.46	67.38	47.56	48.53	56.07^{a}	6.66	56.34	1.67	1.44
45	1168	63.13	64.87	59.65	55.95	64.27	64.79	68.94	48.49	48.29	44.22^{a}	7.60	59.60	1.73	1.51
P	0.294	0.157	0.179	0.265	0.172	0.105	0.593	0.532	0.806	0.541	0.001	0.120	0.870	0.162	0.139
Zn source															
Inorganic	1259	60.79	61.27	55.97	59.11	61.10	63.37	66.79	45.97	45.58	51.20	6.66^{b}	58.21	1.65	1.43
Organic	1236	62.17	63.60	60.40	57.14	62.46	63.62	68.86	50.02	48.36	51.72	7.67^{a}	57.70	1.69	1.48
P	0.698	0.317	0.126	0.050	0.666	0.470	0.870	0.077	0.105	0.319	0.917	0.003	0.898	0.56	0.429
SEM	27.54	0.669	0.724	1.036	2.041	0.866	0.721	0.587	1.178	1.268	2.520	0.258	0.170	0.033	0.029

^{abc}Means with different superscripts in a sub-column differ significantly: P<0.05; P<0.01; BD, Basal diet; 15,1, 30,1 and 45,1 Zn supplementation at 15,30 and 45ppm from inorganic source, 15,O, 30,O and 45,O Zn supplementation at 15,30 and 45ppm from organic source; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; CF, crude fibre; NFE, nitrogen free extract; GE, gross energy; NDF, neutral detergent fibre; ADF, acid detergent fibre; HC,hemicellulose; DCP,digestible crude protein; TDN, total digestible nutrients; DE, digestible energy; ME, metabolizable energy; P, P value; BD vs Zn, basal diet vs Zn supplementation, P value; SEM, standard error mean.

fractions and energy. Though significant differences were observed for digestibility of CP (P<0.05), EE (P<0.05), NDF (P<0.01) and ADF (P<0.05) among various groups, no clear cut trend could be observed and the digestibility of these nutrients by lambs fed Zn supplemented diets were comparable to BD fed lambs. Daghash and Mousa (1999) reported no effect on the digestibility of nutrients due to supplementation of Zn at 4.16, 12.98 or 32.28ppm in lambs, corroborating with the present findings. The digestibility of proximate constituents was comparable to BD (containing 35 and 33ppm Zn, respectively) in Haryana calves supplemented with 20, 40 and 60ppm Zn (Bedi and Sawhney, 1979) and in buffalo calves supplemented with 35 and 70ppm Zn (Jadhav *et al.* 2008).

The comparable digestibilities of proximate constituents among various Zn supplemented groups and BD group resulted in similar total digestible nutrients (TDN) content of the diets (55.65–60.30%) (Table 2). The digestible crude protein (DCP) content of the diets varied from 6.05 to 8.43%, being higher (P<0.01) in organic Zn fed lambs than those fed inorganic Zn. The DCP% was lower (P<0.01) in diets containing 15 or 30ppm Zn from $ZnSO_4$ compared to BD, while comparable among other groups. The digestible (DE) and metabolizable (ME) energy content of diet did not vary due to Zn supplementation (0-45ppm Zn) from either source. The Zn supplementation from 0-70ppm to a BD (33ppm Zn) did not affect the DCP and TDN content of diet in buffalo calves (Jadhav *et al*. 2008) corroborating with the present findings.

No difference (P>0.05) on intake, excretion pattern and balances of nitrogen (N) and energy among the Zn supplemented and BD fed lambs was observed in the present study (Table 3). In the present study the basal diet contained 29.28ppm Zn which might be adequate for optimum nitrogen balance and further increase in dietary Zn concentration did not increase the nitrogen retention. Jadhav *et al.* (2008) reported no affect on nitrogen retention in buffalo calves at 35 or 70ppm of Zn supplementation. The present findings

Table 3. Balances of energy, nitrogen and zinc in lambs fed diets varying in zinc concentration

	Energy (kcal/d)						Nitrogen (g/d)					Zinc (mg/d)				
					Balance					Balance					Balance	
Diet	Intake	Outgo faeces	Urine	Methane	kcal	% intake	Intake	Outgo faeces	Urine	g	% intake	Intake	Outgo faeces	Urine	mg	% intake
BD	4015	1352	19.76	312.4	2331	58.14	24.51	9.82	3.07	11.62	46.80	35.51^{d}	28.78^{d}	3.46^{d}	3.27^{e}	9.06^{d}
15-1	3330	1103	47.09	257.4	1893	57.57	23.40	10.77	2.73	9.90	41.42	57.45^{c}	38.69^{bc}	7.07^{bc}	11.69^{d}	19.67^{c}
15-O	3520	1156	22.30	275.8	2067	59.07	26.60	8.92	3.67	14.01	51.92	58.58^{c}	36.01^{c}	5.13^{cd}	17.44^{d}	29.66^{b}
30-1	3442	1202	48.32	265.2	1927	56.03	24.90	11.11	2.66	11.13	44.31	80.38^{ab}	45.73^{a}	9.46^{a}	25.19^{c}	31.22^{b}
30-O	3336	1012	32.17	266.5	2025	60.69	24.96	11.14	3.33	10.49	41.57	74.46^{b}	36.54^{c}	8.26^{ab}	29.67^{bc}	39.44^{a}
45-1	3478	1097	26.22	275.3	2080	59.73	23.84	9.62	3.17	11.05	43.32	86.12^{ab}	43.35^{ab}	8.08^{ab}	34.69^{ab}	40.04^{a}
45-O	3329	983	37.47	257.7	1951	60.33	24.68	9.84	2.51	12.33	49.96	92.26^{a}	43.05^{ab}	9.37^{a}	39.84^{a}	42.84^{a}
P	0.495	0.139	0.181	0.276	0.431	0.279	0.807	0.130	0.053	0.413	0.163	0.001	0.001	0.001	0.001	0.001
BD vs Zn	0.006	0.013	0.124	0.010	0.014	0.637	0.888	0.572	0.859	0.923	0.769	0.001	0.001	0.001	0.001	0.001
Main factors																
Zn supplementation (ppm)																
0	4015	1352	19.76	312.4	2330.6	58.14	24.51	9.82	3.07	11.62	46.80	35.51^{d}	28.78^{c}	3.46^{c}	3.27^{d}	9.06^{d}
15	3410	1129	34.69	266.6	1979.8	58.32	25.00	9.85	3.20	11.96	46.67	58.02^{c}	37.35^{b}	6.10^{b}	14.57^{c}	24.66^{c}
30	3389	1107	40.25	265.8	1975.8	58.36	24.93	11.12	3.00	10.81	42.94	77.42^{b}	41.13^{ab}	8.86^{a}	27.43^{b}	35.33^{b}
45	3353	1040	31.85	266.5	2015.1	60.03	24.26	9.73	2.84	11.69	47.64	89.19^{a}	43.20^{a}	8.73^{a}	37.26^{a}	41.44^{a}
P	0.958	0.072	0.373	0.088	0.935	0.594	0.951	0.123	0.694	0.852	0.502	0.001	0.001	0.001	0.001	0.001
Zn source																
Inorganic	3407	1134	40.54	265.9	1966	57.77	24.04	10.50	2.85	10.69	43.69	74.65	42.59^{a}	8.20	23.86	30.31^{b}
Organic	3362	1051	30.65	266.8	2014	60.03	25.41	9.97	3.17	12.27	47.82	75.10	38.53^{b}	7.59	28.98	37.31^{a}
P	0.777	0.237	0.225	0.953	0.618	0.044	0.227	0.319	0.214	0.150	0.126	0.936	0.024	0.416	0.182	0.018
SEM	82.46	37.345	3.589	6.375	49.52	0.560	0.525	0.252	0.112	0.499	1.227	3.192	1.038	0.407	2.062	1.874

^{abc}Means with different superscripts in a sub-column differ significantly: $P<0.05$; $P<0.01$; BD, Basal diet; 15–1, 30–1 and 45–1 Zn supplementation at 15,30 and 45ppm from inorganic source, 15–O, 30–O and 45–O Zn supplementation at 15,30 and 45ppm from organic source; P-P value; BD vs Zn- basal diet vs Zn supplementation-P value; SEM- Standard error mean.

are supported by earlier workers who did not find any affect of zinc supplementation on excretion of N through faeces (Bedi and Sawhney 1979, Mandal 2004) and urine (Bedi and Sawhney 1979, Kegley and Spears 1994, Mandal 2004) and its balance (Bedi and Sawhney 1979, Kumar *et al*. 2002, Mandal 2004). The Zn retention (P<0.01) increased in Zn supplemented lambs and the increase was linear with the dose of supplementation (Table 3). Such positive effect of Zn supplementation on its retention was also observed by Kegley and Spears (1994) in lambs, Mandal (2004) in cattle calves and Jadhav *et al.* (2008) in buffalo calves. The excretion of Zn in faeces and urine and retention of Zn was comparable among the two sources at each level of supplementation, though a numerical increase was observed when supplemented as Zn proteinate. Our results are supported by Spears (1989) in lambs fed orchard grass hay based diets supplemented with 20ppm Zn as ZnO or Zn methionine and by Case and Carlson (2002) in pigs supplemented with 500ppm Zn as either ZnO, Zn amino acid complex or Zn polysaccharide.

In the present study, supplementation of Zn at 15, 30 or 45ppm to a BD (29.3ppm Zn) did not improve the weight gains and efficiency of nutrient utilization in lambs throughout the feeding trial of 150days (Table 4). The average daily gain (ADG) ranged between 67.67 and 87.67g in lambs fed BD and Zn supplemented diets (Table 4). Similarly, Galyean *et al.* (1995) observed no affect of dietary Zn source (sulphate or methionine) and concentration (35 or 70 mg of supplemental Zn/kg) during receiving, growing and finishing periods on ADG and feed efficiency of beef heifers. No effect of Zn supplementation was observed on growth and feed efficiency in heifers after initial 56d period at 25ppm (Spears 1989) and steers at 20, 100 or 200 ppm (Malcolm-Callis *et al*. 2000). Similarly, Salyer *et al*. (2004) reported no effect of source of Zn (75ppm) (sulphate or polysaccharide complex) on ADG and gain: feed ratio. The Zn supplementation (25ppm), regardless of Zn source (oxide or proteinate) increased (P<0.05) ADG during 84d growing phase in steers, with no affect on gain: feed ratio (Spears and Kegley 2002). Higher growth rate was reported in buffalo

Table 4. Performance of lambs fed diets varying in zinc concentration

	Growth performance (kg)			Nutrient intake (g or kcal/kg $W^{0.75}$)						Nutrient efficiency (g or kcal intake/g gain)				
Diet	Initial BW	Final BW	Total gain	ADG (g)	DM	CP	DCP	TDN	ME	DM	CP	DCP	TDN	ME
BD	28.37	38.98	10.62	70.78	55.49	11.06	6.66	49.12	117	10.56	2.08	1.26	9.08	21.58
15–1	28.37	39.77	11.40	76.00	55.36	10.77	5.87	53.49	96.9	10.26	1.98	1.08	9.83	18.03
15–O	28.17	41.32	13.15	87.67	55.69	12.00	8.01	51.24	108	9.10	1.94	1.30	8.29	17.24
30–1	28.43	39.85	11.42	76.11	55.68	11.19	6.18	52.84	100	10.89	2.12	1.18	10.02	19.20
30–O	28.17	38.63	10.47	69.78	55.30	11.54	6.39	52.53	108.6	11.95	2.39	1.30	10.77	22.74
45–1	27.90	38.81	10.92	72.78	55.34	10.95	6.56	48.60	115	13.21	2.59	1.56	11.37	25.61
45–O	28.40	38.55	10.15	67.67	55.53	11.15	6.75	49.90	104	11.89	2.35	1.42	10.54	22.58
P	0.999	0.976	0.784	0.784	0.995	0.825	0.973	0.640	0.125	0.764	0.787	0.816	0.808	0.417
BD Vs Zn	0.953	0.827	0.663	0.663	0.999	0.972	0.551	0.985	0.390	0.752	0.692	0.870	0.529	0.847
Main factors														
Zn supplementation (ppm)														
0	28.37	38.98	10.62	70.78	55.49	11.06	6.66	49.12	117	10.56	2.08	1.26	9.08	21.58
15	28.27	40.54	12.28	81.83	55.52	11.39	6.94	52.36	103	9.68	1.96	1.19	9.06	17.63
30	28.30	39.24	10.94	72.94	55.49	11.36	6.29	52.69	105	11.42	2.25	1.24	10.40	20.97
45	28.15	38.68	10.53	70.22	55.43	11.05	6.66	49.25	109	12.55	2.47	1.49	10.95	24.10
P	0.999	0.843	0.568	0.568	0.999	0.973	0.859	0.627	0.360	0.235	0.448	0.530	0.528	0.179
Zn source														
Inorganic	28.23	39.48	11.24	74.96	55.46	10.97	6.20	51.64	104	11.46	2.23	1.28	10.41	20.95
Organic	28.24	39.50	11.26	75.04	55.51	11.56	7.05	51.22	107	10.98	2.22	1.34	9.86	20.86
P	0.995	0.989	0.991	0.991	0.943	0.417	0.173	0.911	0.628	0.752	0.984	0.719	0.653	0.971
SEM	0.742	0.795	0.500	3.331	0.320	0.321	0.277	1.699	0.003	1.34	0.223	0.137	0.987	2.535

BD- Basal diet; 15–1, 30–1 and 45–1 Zn supplementation at 15,30 and 45ppm from inorganic source, 15–O, 30–O and 45-O Zn supplementation at 15,30 and 45ppm from organic source; ADG, average daily gain; BW, body weight; DM, dry matter; CP, crude protein; DCP, digestible crude protein; TDN, total digestible nutrients; ME, metabolizable energy; P- P value; BD vs Zn, basal diet vs Zn supplementation-P value; SEM, standard error mean.

calves supplemented with 50, 100 and 200ppm of Zn (Daghash and Mousa 1999) or those supplemented with 35 and 70ppm Zn (Jadhav *et al*. 2008) compared to unsupplemented calves.

The nutrient intake during the 150d feeding trial is presented in Table 4. The DM, protein (CP, DCP) and energy (TDN, ME) intake per kg metabolic body weight was comparable among all the 7 diets, not affected by dose or source of Zn supplementation. This indicated that Zn concentration in BD was sufficient for optimum growth and feed efficiency. Similarly Jadhav *et al*. (2008) and Mandal (2004) also did not find any difference in the DCP and TDN intake in crossbred calves and Murrah buffaloes supplemented with different levels of Zn in their diet, respectively. The DMI by beef heifers supplemented with 70ppm Zn in form of Zn sulphate, propionate or methionine was comparable to control heifers (no supplemental Zn) in studies of Nunnery *et al*. (2007). Similarly Spears (1989) observed no effect on feed intake in lambs dosed with 300 mg zinc via gelatin capsules in comparison to control lambs.

Carcass characteristics of lambs on diets varying in Zn supplementation is presented in Table 5. The preslaughter weight, hot carcass weight, dressing percentage were not affected (P>0.05) by Zn concentration in diet or by Zn source. The dressing percentage was higher (P<0.10) in lambs fed organic source of Zn compared to inorganic source. The yield of wholesale cuts was similar among the groups except for the yield of rack. The rack yield was more in lambs on 30 and 45 ppm Zn supplementation and in those fed 15 or 30ppm Zn as Zn proteinate compared to BD fed lambs. No affect of Zn was observed on edible and non-edible proportion of the carcass, but significant influence of Zn was recorded on meat, bone and fat proportions. The bone yield was higher (P<0.05) in BD lambs compared to Zn supplemented lambs. A trend of higher (P<0.05) meat yield was observed in lambs consuming $ZnSO_4$ compared to Zn proteinate at all levels of Zn supplementation and the proportion of fat in carcass was more (P<0.05) in lambs on Zn proteinate than $ZnSO_4$. The Zn supplementation had significant (P<0.01) influence on bone meat ratio, being higher in Zn supplemented lambs,

Table 5. Carcass characteristics in lambs varying in zinc concentration

	Slaughter and dressing characteristics					Yield of wholesale cuts (% carcass weight)					Edible and non-edible (% SW)			Meat, bone and fat yield (% carcass weight)			
Attribute	PSW kg	EBW kg	CW kg	DW % SW	DW % EBW	Legs	Lion	Rack	B&FS	N&S	Edible % SW	NE % SW	NE: E	Meat	Bone	Fat	Bone: meat
BD	34.40	33.06	17.93	51.53	53.64	31.81	11.21	12.48^{b}	15.24^{a}	26.11	54.47	21.82	0.42	59.96^{b}	29.37^{a}	10.94^{b}	1.99^{b}
15–1	38.67	37.22	19.79	52.03	53.22	32.26	11.25	12.98^{b}	14.35^{ab}	27.34	55.09	22.46	0.41	62.96^{ab}	24.98^{b}	11.90^{b}	2.52^{a}
15–O	38.63	38.04	19.83	51.34	52.10	32.53	11.81	14.39^{a}	12.43^{bc}	27.41	54.49	21.33	0.39	59.87^{b}	27.68^{ab}	12.45^{ab}	2.18^{ab}
30–1	39.0	37.95	20.14	51.56	53.01	32.85	10.75	12.82^{b}	14.58^{ab}	28.51	54.12	21.30	0.39	64.20^{a}	25.63^{b}	10.05^{b}	2.55^{a}
30–O	37.50	36.47	19.67	52.26	53.73	32.02	11.34	14.03^{a}	14.11^{ab}	28.26	55.07	22.10	0.40	61.42^{ab}	25.20^{b}	12.82^{ab}	2.47^{a}
45–1	36.33	35.25	18.10	49.82	51.36	32.93	11.63	14.46^{a}	10.57^{c}	23.95	52.91	21.07	0.40	63.06^{ab}	25.47^{b}	11.70^{b}	2.48^{a}
45–O	35.33	34.03	19.00	53.75	55.83	32.11	11.72	13.78^{a}	14.93^{a}	29.09	56.68	21.55	0.37	60.06^{b}	24.94^{b}	14.70^{a}	2.42^{a}
P	0.490	0.334	0.736	0.159	0.128	0.926	0.440	0.001	0.002	0.166	0.157	0.447	0.163	0.045	0.031	0.030	0.025
BD vs Zn	0.294	0.218	0.466	0.819	0.888	0.299	0.779	0.019	0.220	0.655	0.854	0.540	0.164	0.883	0.859	0.325	0.009
Main factors																	
Zn supplementation (ppm)																	
0	34.40	33.06	17.93	51.53	53.64	31.81	11.21	12.48^{b}	15.24	26.11	54.47	21.82	0.42	59.96	29.37^{a}	10.94	1.99^{a}
15	38.65	37.63	19.81	51.69	52.66	32.40	11.53	13.69a	13.39	27.27	54.79	21.90	0.40	61.41	26.33^{b}	12.17	2.35^{b}
30	38.25	37.21	19.90	51.91	53.37	32.44	11.04	13.43a	14.34	28.38	54.59	21.70	0.40	62.80	25.42^{b}	11.44	2.51^{b}
45	35.83	34.64	18.55	51.79	53.59	32.52	11.68	14.12a	12.75	26.52	54.79	21.31	0.38	61.56	25.21b	13.20	2.45b
P	0.153	0.088	0.348	0.991	0.848	0.880	0.320	0.011	0.164	0.511	0.990	0.681	0.163	0.333	0.014	0.228	0.014
Zn source																	
Inorganic	38.00	36.81	19.34	51.14	52.53	32.68	11.21	13.42	13.17	26.60	54.04	21.61	0.40	63.40	25.36	11.22	2.52
Organic	37.16	36.18	19.50	52.45	53.89	32.22	11.62	14.07	13.82	28.25	55.41	21.66	0.39	60.45	25.94	13.32	2.35
P	0.457	0.565	0.815	0.073	0.130	0.378	0.181	0.047	0.441	0.186	0.049	0.908	0.197	0.002	0.466	0.010	0.104
SEM	0.700	0.682	0.416	0.364	0.424	0.267	0.138	0.164	0.381	0.540	0.352	0.186	0.004	2.079	1.920	0.389	0.054

[abc]Means with different superscripts in a sub-column different significantly: $P<0.05$; $P<0.01$. BD- Basal diet; 15–1, 30–1 and 45–1 Zn supplementation at 15,30 and 45ppm from inorganic source, 15–O, 30–O and 45–O Zn supplementation at 15,30 and 45ppm from organic source; PSW, preslaughter weight; EBW, empty body weight; CW, carcass weight; DW, dressed weight; B and FS, breast and foreshank; N&S, neck and shoulders; NE, non-edible; NE: E, non-edible : edible; P- P value; BD vs BD, basal diet vs Zn supplementation; SEM, standard error mean.

with no affect of dose or source of Zn. Such observations were reported by previous workers in steers (Greene *et al*. 1988, Malcolm-Callis *et al*. 2000). Supplementation of Zn (360 mg Zn/d) to a control diet (containing 82ppm Zn) as Zn oxide did not affect carcass traits, but Zn methionine increased fat thickness, percentage of kidney, pelvic and heart fat compared to control and ZnO supplemented steers (Greene *et al*. 1988). Addition of 20, 100 or 200 mg Zn/kg DM to a finishing diet (containing 70 mg/kg DM) had no affect on carcass weight and dressing percentage but resulted in a quadratic increase in fat thickness (Malcolm-Callis *et al*. 2000). The same workers observed lower percentage of kidney, pelvic and heart fat and subcutaneous fat thickness for steers supplemented with 30ppm Zn from $ZnSO_4$ than that supplemented from organic sources (Zn amino acid or Zn polysaccharide complex). Supplementation of 35 or 70 mg Zn/kg DM did not affect carcass characteristics in steers (Galyean *et al*. 1995). While, Spears and Kegley (2002) reported higher carcass weight, dressing percentage and back fat thickness in steers fed BD (26ppm Zn) supplemented with 25ppm Zn as Zn oxide or proteinate.

The results of this study indicated that supplementation of zinc to a growing diet containing 29.3ppm (meeting the NRC 1985 recommendations) appears to be sufficient for maximum growth performance, carcass characteristics, nutrient digestibilites and balances of nitrogen and energy in lambs, except for bone, meat and fat proportion in carcass. The proportion of meat to bone was higher in Zn supplemented lambs. The source of Zn in diet influenced the meat and fat proportion in carcass, the meat % was higher and fat % was lower in lambs fed Zn sulphate compared to Zn proteinate.

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