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THE INFLUENCE OF BETAINE SUPPLEMENTATION ON THE DELETERIOUS EFFECTS OF SALINE WATER CONSUMPTION ON CARCASS CHARACTERISTICS AND MEAT QUALITY OF GROWING LAMBS

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SUMMARY

This study aimed to evaluate the impact of betaine supplementation on the deleterious effects of saline water consumption on carcass characteristics and meat quality of growing lambs. Twenty lambs were assigned to four treatments; control (S0B0), saline water (1.5% NaCl) without betaine group (S1B0), fresh water with betaine group (2500 mg betaine /kg concentrate diet) (S0B1) and saline water with betaine group(S1B1) in 2×2 factorial arrangement. Lambs were reared under the experimental condition for five months. At the end of experiment, three lambs were randomly chosen from each treatment and slaughtered after 12 h fasting. After slaughter, the hot carcass weights and organs weights were recorded. Then, the carcass measurements, commercial carcass cuts weight and percentage were determined. Meat samples of the semimembranosus muscle, longissimus dorsi muscle, and supraspinatus muscle were obtained and prepared for meat quality measures. Saline water significantly ($P<0.01$) decreased hot carcass weight, empty body weight, internal organs and carcass parts. In addition, saline water significantly ($P<0.01$) decreased the loin percentage. However, betaine significantly ($P<0.01$) increased the hot carcass weight, empty body weight ($P<0.05$), internal organs ($P<0.05$). In addition, betaine significantly increased almost of carcass commercial cuts. In general, consuming saline water negatively affect lambs' carcass characteristics and meat quality. While, betaine supplementation improved lambs' carcass characteristics and meat quality. Consequently, when lambs consume saline water with betaine ameliorates the deleterious effects of saline water consumption on carcass characteristics and meat quality.

Keywords: meat quality, betaine, lambs, water salinity, carcass

INTRODUCTION

Overpopulation and increased demand per individual together with the quick income growth are reflected in increased demand for both staple and preferred foods, especially, meat products (Bender, 1992). The growing demand for meat products that accompanies rising income has been paralleled. Consequently, the increased interest in food quality, safety, and nutritional aspects demand to produce more meat with high quality. One of the most important challenges in meat production industry is the water shortage, especially in the arid and semi-arid regions. According to Ayers and Westcot (1985), in the arid and semi-arid regions of the world livestock commonly use poor or marginal quality drinking water for several months of the year. These supplies originate from small wells, canals, streams or water holes, of which only the better are also used for irrigation. To avoid water scarcity, countries must increase their use of other water resources such as groundwater which would be the main source of used water in cultivated desert lands. However, the sources of drinking water in arid areas contain high concentrations of salts with NaCl as the main constituent (Gihad, 1993). Carcass traits were adversely affected by saline water according to many studies. For instance, Marai *et al*. (2005) showed a significant ($P<0.05$) decrease in slaughter weight, carcass weight, trunk weight, hind limbs weight, liver, and kidneys (with fat) weights in rabbits offered saline water (5000 ppm TDS) compared with tap water group. On the other hand, Virtanen (1995) showed that betaine enhances the animals' growth and metabolism during its exposure to various physiological stresses such as drought or high salinity. Betaine gathers inside the cell exposed to osmotic stress and prevent enzymes and cell membranes from inactivation by inorganic ions (Petronini *et al*., 1992).

The objective of the present study is to evaluate the ability of betaine to ameliorate the harmful effects of water salinity stress and to investigate its effect on carcass characteristics and meat quality of lambs.

MATERIALS AND METHODS

Animals and feeding:

The study was developed in the research farm of Animal Production Department, Faculty of

Agriculture, South Valley University, Qena, Egypt, located at latitude 26°11'02.4"N and longitude 32°44'23.1"E. Twenty Ossimi male lambs, 9 months of age, and initial body weight of 31.5 kg, were used. Animals were housed in opened shaded pens and were fed on of wheat straw (*Triticum aestivum*) and a commercial concentrate mixture, with roughage: concentrate ratio of 20:80. The animals' requirements were calculated according to NRC (2007).

Experimental procedure:

The twenty Ossimi lambs were assigned to four treatments (5 replicates of each) with 2×2 factorial arrangement of treatments in Randomized Complete Block Design (RCBD). Lambs were provided with NaCI in drinking water at the levels of 0% (S0) and 1.5% (S1). Betaine (Betafin, Danisco Animal Nutrition, Cairo, Egypt) was added to the concentrate mixture at the level of 0 (B0) and 2500 mg/kg (B1) concentrate mixture. Thus, the array of treatment groups was the control group (S0B0), saline water group (S1B0), betaine group (S0B1) and saline water with betaine group (S1B1).

At the end of the experiment period (135 days), twelve lambs (3 from each group), were fasted (for 12 h) with free access to water before slaughter. Lambs were weighed before slaughter. Thereafter, lambs were slaughtered at a slaughterhouse which is located on the same farm according to the Islamic tradition, Halal as outlined in Malaysian Standard (2009). Thereafter the head was removed at the atlanto-occipital joint, the fore feet removed at the carpal and the hind feet removed at the tarsal joints. The dressing was done by removing the external and internal organs.

Moreover, some internal organs (liver, testes, and kidneys) were immediately recorded and the tail's fat weight was recorded. In addition, the empty rumen and intestine were weighed. Thereafter, the caul fat of rumen, omental fat of intestines and perirenal fat near the kidney were weighed. Subsequently, the hot carcass weight was recorded. Empty body weight was calculated as the whole animal weight without the contents of the gastrointestinal tract. Moreover, full dressing percentage was calculated as the percentage of hot carcass weight in respect to live body weight. While empty dressing percentage was calculated as the percentage of hot carcass weight in respect to empty body weight.

Carcass measurements (carcass length, internal carcass length, carcass depth, neck length, leg length, leg circumference, lumber region length, buttock circumference over tail, and leg circumference under tail) were obtained directly on hot carcass. The carcass length was measured from the hock joint to the dorso-cranial edge of the atlas (1st cervical vertebra). In addition, internal carcass length was determined from 1strib to aitch bone. The carcass depth at 7thrib was measured in a horizontal position subsequently neck length was measured from atlas to the last cervical vertebra. Moreover, leg length was from hock joint to aitch bone, leg circumference at 50% of length was recorded. In addition, the lumbar region length was measured. Moreover, buttock circumference over tail and leg circumference under the tail head was measured as the greatest depth in a horizontal plane according to Fisher and De Boer (1994).

Subsequently, carcass was separated along the midline into right and left sides which were individually weighed. The left side was separated into seven cuts as suggested by Strydom *et al.*, (2009). These carcass cuts were loin, shoulder, rack (ribs), brisket, round, neck, and flank. 9th to11th ribs section was separated from the left side. Following the procedure described by Morais *et al*. (2016), the section was weighted and separated to its components (muscle, fat, and bone). Thereafter the components were weighed, and the percent of each component was calculated in respect to the whole section weight (Ledger and Hutchison, 1962). The semimembranosus muscle (SM), longissimus dorsi muscle (LD), and supraspinatus muscle (SP) were dissected then weighed and used for meat quality measures (water holding capacity, cooking loss and meat pH).

For determining the water holding capacity, about 0.3 g from meat was placed above filter paper and covered by a piece of butter paper, then placed between two sheets of glass, in which a weight of 1 kg was placed on the top of the upper glass sheet for 10 minutes to generate adequate pressure. Then, the samples were reweighed. Water holding capacity was expressed as the percentage of loss related to the initial weight.

For determining cooking loss, approximately 5 g of meat sample was placed inside a water bath at 100°C for 30 min until the internal temperature of the meat reached 75°C according to Boccard *et al.*(1981). Subsequently, they were kept at room temperature for 30 minutes, dried with filter paper and reweighed. Cooking loss was expressed as the percentage of loss related to the initial weight.

Then, meat pH was determined using a digital pH meter (Model AD1030). About 10 g of the sample was cut into small pieces and added to 10 ml of distilled water. The electrodes were washed with distilled water and dried with filter paper. Then, the spear electrode was inserted into the sample and pH meter read was recorded.

Statistical Analysis of data:

Data were statistically analyzed using SAS software version 9.4 2013.The statistical analysis model was $Y_{ijk} = \mu + S_i + B_j + (SB)_{ij} + C_k + \epsilon_{ijk}$; where Y_{ijk} is the observation, μ is the general mean, S_i is the effect of ith level of saline water, B_j is the effect of jth level betaine, (SB) ij is the interaction between ith level of saline water and jth level of betaine, C_k is the effect of kth block, $\epsilon_{ijk}$is the effect of error. When factors effects were significant, differences between means were tested using Duncan's multiple-range test, and the differences were considered significant at the level of $P<0.05$. Differences between treatments (interactions) were tested using PIDFF procedure.

RESULTS

Carcass weight, dressing percentage, and organs weight:

The results of carcass weight, dressing percentage, and organs weights are shown in Tables (1 and 2). The results showed that saline water significantly ($P<0.01$) decreased final body weight, hot carcass, empty body weight and liver weight than the fresh water group. Moreover, saline water slightly decreased the dressing percentage, but the difference was not significant. On the other hand, betaine supplementation(2500 mg/kg concentrate mixture) improved carcass weight ($P<0.01$) and empty body weight ($P<0.05$). Moreover, betaine supplementation significantly ($P<0.05$) increased the tests weight by 37.03%. In addition, betaine supplementation significantly ($P<0.05$) increased the liver weight. Also, betaine slightly but not significantly increased the dressing percentage. The interaction effect was only significant on the case of tests weight. In contrast fat storages were not affected by saline water, betaine or their interaction.

Betaine supplementation for lambs consumed saline water (S1B1) improved final weight by 7.47%, hot carcass by 12.43, empty body weight by 9.33% and 4.97% improvement in dressing percent compared with lambs consumed saline water without betaine supplementation (S1B0).

Table 1. Hot carcass weight, empty body weight, and dressing percentage of lambsas affected by saline water, betaine and their interaction

Factors	Final body weight(Kg)	Hot carcass weight (Kg)	Empty body weight (Kg)	Dressing % full	Dressing % empty
Salinity	**0.0009**	**<.0001**	**0.0006**	**0.536**	**0.1545**
Fresh	44.83^{a}±2.20	19.69^{a}±1.06	36.32^{a}±1.86	43.94±1.16	54.21±0.90
1.5 % NaCl	34.68^{b}±1.07	14.94^{b}±0.55	28.38^{b}±1.03	43.07±0.87	52.65±0.49
Betaine	**0.0399**	**0.001**	**0.0113**	**0.0882**	**0.1389**
0 mg	37.34^{b}±1.82	15.78^{b}±0.84	29.96^{b}±1.45	42.21±0.60	52.62±0.67
2500 mg	42.17^{a}±3.26	18.86^{a}±1.42	34.74^{a}±2.53	44.80±1.08	54.25±0.76
Interaction					
S_0B_0	41.25^{b}±0.18	17.48^{b}±0.39	32.80^{b}±0.49	42.39±1.12	53.31±1.12
S_0B_1	48.40^{a}±3.37	21.90^{a}±0.78	39.83^{a}±2.14	45.48±1.77	55.11±1.41
S_1B_0	33.43^{c}±1.10	14.07^{c}±0.68	27.12^{b}±1.50	42.03±0.70	51.92±0.72
S_1B_1	35.93^{bc}±1.71	15.82^{bc}±0.52	29.65^{b}±1.20	44.12±1.50	53.38±0.41

a, b and c refer to means within the same column with different superscripts for each factor are significantly different ($P<0.05$), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Table 2. Internal organs and fat stores of lambs as affected by saline water, betaine and their interaction

Factors	Empty rumen (Kg)	Empty Intestine (Kg)	Caul Fat (g)	Omental fat (g)	Tail fat (Kg)	Tests (Kg)	Liver(g)	Kidney (g)	Kidney fat (g)
P- value of salinity	**0.3456**	**0.2424**	**0.4259**	**0.7154**	**0.4243**	**0.3945**	**<.0001**	**0.0943**	**0.0749**
Fresh	1.26±0.12	1.22±0.07	259.17±61.72	223.33±43.43	2.46±0.43	0.33±0.05	525.83^{a}±12.61	102.50±3.35	106.67±19.86
1.5 % NaCl	1.13±0.07	1.10±0.08	194.17±59.64	210.00±12.11	1.93±0.38	0.31±0.02	344.17^{b}±11.29	112.50±4.96	60.00±16.48
P- value of betaine	**0.0585**	**0.2424**	**0.0805**	**0.1028**	**0.8329**	**0.0231**	**0.0194**	**0.0578**	**1.0000**
0 mg	1.06±0.05	1.10±0.07	149.17±28.24	184.17±30.43	2.12±0.33	0.27^{b}±0.02	415.83^{b}±42.88	101.67±2.79	83.33±12.69
2500 mg	1.33±0.11	1.22±0.07	304.17±67.74	249.17±26.50	2.26±0.50	0.37^{a}±0.04	454.17^{a}±40.01	113.33±4.94	83.33±26.88
Interaction									
S_0B_0	1.1±0.10	1.23±0.07	161.67±48.51	151.67^{b}±56.00	2.26±0.33	0.23^{b}±0.01	508.33^{a}±21.67	96.67^{b}±3.33	81.67^{ab}±13.33
S_0B_1	1.42±0.20	1.20±0.13	356.67±84.77	295.00^{a}±34.03	2.65±0.89	0.44^{a}±0.05	543.33^{a}±4.41	108.33^{ab}±3.33	131.67^{a}±34.20
S_1B_0	1.02±0.02	0.97±0.03	136.67±38.44	216.67^{ab}±20.88	1.98±0.64	0.32^{b}±0.03	323.33^{b}±13.02	106.67^{ab}±1.67	85.00^{ab}±25.00
S_1B_1	1.25±0.10	1.23±0.11	251.67±114.03	203.33^{ab}±15.90	1.87±0.54	0.30^{b}±0.02	365.00^{b}±5.77	118.33^{a}±9.28	35.00^{b}±10.41

a, b and c refer to means within the same column with different superscripts for each factor are significantly different ($P<0.05$), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Carcass measurements:

The carcass measurements are presented in Table (3). Consuming saline water significantly ($P<0.05$) decreased the buttock circumference over tail by 9.13%. Moreover, saline water ($P<0.01$) decreased the leg circumference under the tail by 9.58%. However, saline water did not affect the other carcass measurements.

Betaine supplementation slightly increased the buttock circumference over tail. In addition, betaine significantly ($P<0.01$) increased the leg circumference under the tail by 9.69%. The least square means comparisons between the four groups of interaction showed an improvement of carcass measurements in S1B1 group compared with S1B0 group. In addition, betaine supplementation for lambs consumed saline water (S1B1) improved Leg circumference at 50% of the length by 6.13%, Buttock circumference by 10.3% and Leg circumference under the tail by 9.98% compared with those consume saline water without betaine supplementation (S1B0).

Table 3. Carcass measurements (cm) of lambs as affected by saline water, betaine and their interaction

Factors	Carcass Length (cm)	Internal carcass length (cm)	Carcass depth (cm)	Leg length (cm)	Leg circumference at 50% of the length (cm)	Lumber region length (cm)	Neck length (cm)	Buttock circumference (cm)	Leg circumference under the tail (cm)
P- value of salinity	**0.1854**	**0.0572**	**0.6869**	**0.3116**	**0.5761**	**0.9397**	**0.6288**	**0.0312**	**0.0033**
Fresh	125.42±2.17	72.17±3.05	28.25±0.81	41.50±0.96	23.00±0.67	24.5±0.52	25.42±0.58	46.50^{a}±0.83	42.58^{a}±0.93
1.5 % NaCl	121.58±1.07	65.17±0.70	27.83±0.38	40.33±0.42	22.50±0.61	24.58±0.87	25.00±0.59	42.25^{b}±1.55	38.50^{b}±1.15
P- value of betaine	**0.7608**	**0.2993**	**0.8082**	**0.3116**	**0.1185**	**0.5021**	**0.3011**	**0.1298**	**0.0053**
0 mg	123.08±0.95	66.92±1.25	27.92±0.49	40.33±0.71	22.00±0.74	24.92±0.75	24.75±0.51	43.00±1.62	38.67^{b}±1.05
2500 mg	123.92±2.52	70.42±3.45	28.17±0.76	41.50±0.76	23.50±0.26	24.17±0.64	25.67±0.60	45.75±1.23	42.42^{a}±1.16
Interaction									
S_0B_0	124.33±0.88	69.17^{ab}±1.42	28.00±1.00	40.67±1.45	22.17±1.17	24.50±0.76	25.33±0.33	45.83^{a}±0.93	40.67^{b}±0.33
S_0B_1	126.50±4.65	75.17^{a}±5.96	28.50±1.50	42.33±1.33	23.83±0.44	24.50±0.87	25.50±1.26	47.17^{a}±1.45	44.50^{a}±0.76
S_1B_0	121.83±1.48	64.67^{b}±0.88	27.83±0.44	40.00±0.58	21.83±1.17	25.33±1.42	24.17±0.93	40.17^{b}±2.05	36.67^{c}±1.20
S_1B_1	121.33±1.86	65.67^{ab}±1.20	27.83±0.73	40.67±0.67	23.17±0.17	23.83±1.09	25.83±0.44	44.33^{ab}±1.86	40.33^{b}±1.33

a, b and c refer to means within the same column with different superscripts for each factor are significantly different (P<0.05), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Carcass parts and parts percent:

Carcass parts and parts percentages are shown in Tables (4 and 5). Saline water significantly (P<0.01) decreased theweights of right side, left side, shoulder, flank (Table 5), brisket, round, neck, loin and rack. In addition, saline water significantly (P<0.01) decreased the loin percentage. However, no significant differences were observed between saline water group and fresh water group in the other carcass parts percentages (right side, left side, shoulder, brisket, flank, round, neck and rack).

In contrast, betaine supplementation significantly (P<0.01) increased the weights of the right side, left side, shoulder, round and loin. Moreover, betaine supplementation increased (P<0.05) the rack weight. On the other hand, betaine did not affect carcass parts percentages (right side, left side, shoulder, brisket, flank, round, neck and loin). The least square means analysis between the four groups of interaction showed significant differences on the weight of right side, flank weight (P<0.05), rack weight (P<0.01).

Betaine supplementation for lambs consuming saline water (S1B1) non significantly increased all carcass parts weight compared with those consume saline water without betaine (S1B0).

Table 4. Carcass's parts weight of lambs as affected by saline water, betaine and their interaction

Factors	Right side (Kg)	Left side(Kg)	Shoulder (Kg)	Flank (Kg)	Brisket (Kg)	Round (Kg)	Rack (Kg)	Neck (Kg)	Loin (Kg)
P- value of salinity	**<.0001**	**<.0001**	**<.0001**	**0.0068**	**0.0021**	**0.0011**	**0.0044**	**0.009**	**<.0001**
Fresh	9.74^{a}±0.55	9.95^{a}±0.51	1.92^{a}±0.10	0.27^{a}±0.03	0.87^{a}±0.05	3.27^{a}±0.15	1.44^{a}±0.11	0.96^{a}±0.06	1.23^{a}±0.07
1.5 % NaCl	7.44^{b}±0.26	7.50^{b}±0.29	1.46^{b}±0.06	0.19^{b}±0.01	0.65^{b}±0.02	2.55^{b}±0.15	1.08^{b}±0.05	0.75^{b}±0.04	0.82^{b}±0.03
P- value of betaine	**0.0011**	**0.0011**	**0.0012**	**0.0814**	**0.1029**	**0.0074**	**0.0298**	**0.0708**	**<.0001**
0 mg	7.82^{b}±0.40	7.96^{b}±0.45	1.54^{b}±0.09	0.21±0.01	0.71±0.04	2.65^{b}±0.17	1.14^{b}±0.06	0.79±0.05	0.92^{b}±0.07
2500 mg	9.37^{a}±0.71	9.49^{a}±0.72	1.84^{a}±0.13	0.25±0.03	0.80±0.07	3.17^{a}±0.20	1.38^{a}±0.13	0.92±0.07	1.13^{a}±0.11
Interaction									
S_0B_0	8.60^{b}±0.25	8.88^{b}±0.14	1.73^{b}±0.05	0.22^{ab}±0.02	0.78^{ab}±0.05	2.98^{ab}±0.08	1.26^{ab}±0.01	0.85^{ab}±0.04	1.07^{b}±0.03
S_0B_1	10.88^{a}±0.39	11.02^{a}±0.40	2.11^{a}±0.08	0.32^{a}±0.03	0.95^{a}±0.07	3.57^{a}±0.12	1.62^{a}±0.16	1.06^{a}±0.08	1.39^{a}±0.02
S_1B_0	7.03^{c}±0.34	7.03^{c}±0.34	1.35^{c}±0.03	0.20^{b}±0.03	0.64^{b}±0.04	2.33^{b}±0.18	1.02^{b}±0.05	0.73^{b}±0.07	0.76^{c}±0.04
S_1B_1	7.85^{bc}±0.23	7.97^{bc}±0.30	1.57^{bc}±0.07	0.19^{b}±0.02	0.65^{b}±0.03	2.77^{b}±0.18	1.14^{b}±0.07	0.77^{b}±0.04	0.88^{c}±0.02

a, b and c refer to means within the same column with different superscripts for each factor are significantly different (P<0.05), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Table 5. The Carcass's parts percent of lambs as affected by saline water, betaine and their interaction

Factors	Right side %	Left side %	Shoulder %	Flank %	Brisket %	Round %	Neck %	Loin %	Rack %
P- value of salinity	**0.1914**	**0.1914**	**0.7461**	**0.4807**	**0.9945**	**0.381**	**0.4923**	**0.0079**	**0.9714**
Fresh	49.44±0.22	50.56±0.22	19.33±0.43	2.71±0.17	8.69±0.28	32.95±0.48	9.58±0.25	12.36 ^{a}±0.36	14.38±0.44
1.5 % NaCl	49.82±0.18	50.18±0.18	19.52±0.29	2.54±0.18	8.69±0.27	33.85±0.85	10.07±0.58	10.93 ^{b}±0.15	14.40±0.27
P- value of betaine	**0.767**	**0.767**	**0.8661**	**0.9596**	**0.1631**	**0.7661**	**0.6425**	**0.3804**	**0.8345**
0 mg	49.59±0.24	50.41±0.24	19.37±0.30	2.63±0.17	8.97±0.23	33.25±0.68	9.99±0.50	11.45±0.37	14.33±0.19
2500 mg	49.67±0.19	50.33±0.19	19.47±0.43	2.62±0.19	8.41±0.26	33.55±0.75	9.66±0.39	11.83±0.45	14.45±0.48
Interaction									
S_0B_0	49.17±0.34	50.83±0.34	19.45±0.30	2.50±0.22	8.78±0.47	33.48±0.45	9.56±0.36	12.08^{ab}±0.52	14.15±0.28
S_0B_1	49.70±0.22	50.30±0.22	19.20±0.90	2.92±0.22	8.61±0.40	32.42±0.82	9.61±0.44	12.64 ^{a}±0.54	14.61±0.92
S_1B_0	50.00±0.00	50.00±0.00	19.30±0.60	2.76±0.28	9.16±0.09	33.02±1.44	10.42±0.98	10.83 ^{b}±0.10	14.51±0.27
S_1B_1	49.65±0.36	50.35±0.36	19.74±0.14	2.32±0.19	8.21±0.38	34.68±0.93	9.72±0.76	11.02 ^{b}±0.31	14.30±0.52

a, b and c refer to means within the same column with different superscripts for each factor are significantly different (P<0.05), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Best rib components weight and percent:

Saline water significantly (P<0.05) decreased the best rib weight and best rib fat weight but did not affect the best rib bone or meat weight (Table 6). On the other hand, betaine supplementation did not affect any of best rib weight, its components weight or percent. The least square means analysis between the four groups of interaction showed significant differences on best rib meat percentage (P<0.01), and both weight and percentage of best rib fat (P<0.01). S1B1 group had more meat and less fat in its best rib compared with S1B0 group. Moreover, the percent of meat was higher (P<0.05) and the percent of fat was lower (P<0.05) in S1B1 compared with S1B0 group.

Table 6. The best rib and its components weight and percentages of lambs as affected by saline water, betaine and their interaction

Factors	Best rib (Kg)	Best rib meat (g)	Best rib fat (g)	Best rib bone (g)	Best rib meat %	Best rib fat %	Best rib bone %
P- value of salinity	**0.0322**	**0.066**	**0.0291**	**0.1172**	**0.0526**	**0.0625**	**0.7614**
Fresh	0.40 ^{a}±0.05	230.00±19.66	95.00 ^{a}±24.12	73.33±9.10	58.95±2.44	22.32±3.45	18.73±1.86
1.5 % NaCl	0.29 ^{b}±0.02	185.00±13.66	49.17 ^{b}±10.12	55.00±2.58	63.88±2.35	16.55±2.59	19.57±1.96
P- value of betaine	**0.1034**	**0.0746**	**0.1122**	**0.7577**	**0.7226**	**0.3936**	**0.2655**
0 mg	0.31±0.02	185.83±12.68	56.67±9.63	62.50±7.72	61.02±1.64	18.23±2.49	20.75±2.28
2500 mg	0.38±0.05	229.17±20.67	87.50±26.58	65.83±7.90	61.81±3.34	20.64±3.89	17.55±1.06
Interaction							
S_0B_0	0.32±0.03	200.00±7.64	50.00 ^{b}±10.41	70.00±15.28	62.94^{ab}±2.99	15.57 ^{bc}±3.13	21.49±3.08
S_0B_1	0.48±0.07	260.00±31.22	140.00^{a}±27.84	76.67±13.02	54.97^{c}±2.24	29.07^{a}±2.01	15.97±0.40
S_1B_0	0.29±0.04	171.67±23.33	63.33^{ab}±17.64	55.00±2.89	59.10^{bc}±0.92	20.90 ^{ab}±3.76	20.01±4.00
S_1B_1	0.29±0.01	198.33±14.53	35.00 ^{b}±0.00	55.00±5.00	68.66 ^{a}±1.99	12.21^{c}±0.65	19.13±1.71

a, b and c refer to means within the same column with different superscripts for each factor are significantly different (P<0.05), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

Muscle weight and meat quality:

Saline water significantly decreased the supraspinatus muscle weight (P<0.01) and the semimembranosus muscle weight (P<0.05). However, saline water did not affect the weight of *longissimus dorsi* muscle (Table 7). Moreover, the weights of supraspinatus, semimembranosus and *longissimus dorsi* muscles were higher in betaine group than the 0% betaine group, but the increase was only significant (P<0.05) incase of supraspinatus muscle.

Water holding capacity, cooking loss and pH are shown in Table (7). Neither saline water nor betaine affected water holding capacity and pH of meat samples. In addition, saline water did not affect the cooking loss of semimembranosus muscle or *longissimus dorsi* muscle. However, betaine significantly (P<0.05) increased the cooking loss of *longissimus dorsi* muscle but did not affect the cooking loss of semimembranosus muscle. The interaction between betaine and saline water showed no significant differences between the four groups. S1B1 lambs had slightly higher muscle weight than those in S1B0 treatment. However, there were no differences between the two treatments in meat quality treats.

Table 7. The weights of supraspinatus muscle (SP), semimembranosus muscle (SM), longissimus dorsi muscle (LD) and Meat quality traits of lambs as affected by saline water, betaine and their interaction

Factors	SP (g)	SM (g)	LD (g)	WHC		Cooking loss		pH
				SM muscle	LD muscle	SM muscle	LD muscle	
P- value of salinity	**0.0025**	**0.0144**	**0.2675**	**0.1871**	**0.9242**	**0.8336**	**0.8023**	**0.6339**
Fresh	127.50 ^{a}±4.23	120.83^{a}±11.86	80.83±7.00	32.64±0.81	34.66±1.38	52.18±0.48	45.16±1.38	5.74±0.05
1.5 % NaCl	104.17 ^{b}±5.39	87.50 ^{b}±4.96	70.00±4.83	36.94±2.60	34.46±1.36	52.67±1.97	45.64±1.75	5.77±0.05
P- value of betaine	**0.024**	**0.0986**	**0.4333**	**0.781**	**0.7662**	**0.6476**	**0.0417**	0.0686
0 mg	108.33 ^{b}±7.15	94.17±5.54	71.67±6.67	35.22±0.94	34.87±1.08	52.96±0.75	43.15^{b}±1.05	5.70±0.03
2500 mg	123.33 ^{a}±5.27	114.17±14.34	79.17±5.83	34.36±2.88	34.25±1.60	51.90±1.86	47.65^{a}±1.36	5.81±0.05
Interaction								
S_0B_0	121.67 ^{a}±4.41	101.67^{ab}±3.33	78.33±10.93	33.83±0.22	35.99±1.79	52.62±0.94	43.57±1.20	5.73±0.05
S_0B_1	133.33 ^{a}±6.01	140.00^{a}±18.03	83.33±10.93	31.44±1.34	33.34±2.14	51.75±0.25	46.76±2.35	5.75±0.09
S_1B_0	95.00 ^{b}±7.64	86.67 ^{b}±9.28	65.00±7.64	36.60±1.55	33.76±1.18	53.30±1.35	42.74±1.97	5.67±0.03
S_1B_1	113.33^{ab}±1.67	88.33 ^{b}±6.01	75.00±5.77	37.27±5.59	35.16±2.71	52.04±4.16	48.55±1.72	5.87±0.02

a, b and c refer to means within the same column with different superscripts for each factor are significantly different (P<0.05), for interaction comparisons pairwise tests of differences (PDIFF) were used. The treatments are fresh water without betaine (S_0B_0), fresh water with betaine (S_0B_1), saline water without betaine (S_1B_0) and betaine with saline water (S_1B_1).

DISCUSSION

Consuming saline water causes salinity stress. In turn, salinity stress leads to many metabolic changes to help the animal's body adapting with the stress. The metabolic changes negatively affected animals' performance, carcass characteristics and meat quality. In the current study, lambs consumed saline water had low carcass weight, low carcass parts weight and different parts percentages. In general, animals consume saline water attending to drink more water to help the kidneys flushing excess sodium (Meintjes and Engelbrecht, 2004). Instead of flushing sodium from the kidneys, animals consume and absorb more sodium chloride since they are offered saline water. The high absorbed sodium chloride generates a state of general illness which is mainly due to lower feed intake (Phillip *et al*., 1981). Moreover, a strong relation was established between feed intake and both hot carcass weight and 12th rib backfat (Murphy and Loerch 1994). Additional reason of low carcass characteristics associated with consuming saline water is thyroid hormones. Offering saline water decreases thyroid hormones secreted in blood plasma (Abd-El-Moneim and Lotfi, 2010). Low level of thyroid hormones reduces protein synthesis through inhibition of synthesis hepatic RNA (Tata and Widnell, 1966). Subsequently, low level of protein synthesis decreases body weight and carcass weight (Habeeb *et al*. 1998).

Similar to present results, Croom *et al.* (1985) showed a reduction on carcass weight (P<0.05) in steers by adding 5% NaCl in feed. In addition, Maraie*t al.* (2005) showed that offering saline water (5000 ppm TDS) to rabbits significantly (P<0.05) decreased the carcass weight, pre-slaughter weight, and liver weight compared with tap water group.

In the current study, lambs consumed saline water showed low carcass measurements (leg circumference under the tail and buttock circumference over tail) this finding might be due to the lower body weight. Moreover, Sebsibe *et al*. (2007) found similar results, lower body weight leads to lower (P<0.01) carcass measurements of goats.

However, saline water slightly decreased the dressing percentage, but the effect was not significant. These findings are reliable with those of Hekal (2015) who showed that consuming saline water did not affect the dressing percentage of Barki ram lambs. Moreover, Yousfi*et al.* (2016) found that consuming saline water did not affect the weight of both full and empty digestive tract, the tail weight of Barbarine lamb.

Similar to many studies, meat quality measures, water holding capacity, cooking loss and pH were not affect by saline water consumption. In lambs, Castro *et al*. (2017) reported that saline water (8326 mg TDS/l) did not affect the water holding capacity of meat. In the same time, Yousfi *et al*. (2016) found saline water (7 g NaCl /l) did not affect the cooking loss of lambs' meat. Similarly, in sheep, Pearce *et al*. (2008) showed that salt load from the consumption of halophytes such as saltbush did not affect meat pH.

In contrast, betaine supplementation improved the carcass characteristics (carcass weight, organs weight, carcass parts weights and carcass parts percentages). Betaine acts as an osmolyte, methyl donor, and carcass modifier(Eklund *et al*. 2005) through its involvement in protein and energy metabolism. Another finding is increased buttock circumference of betaine supplemented lambs in the current study. Subsequently, the increased buttock circumference indicates higher carcass lean content. In addition, Lambe *et al*. (2009) showed higher correlations between buttock circumference and dissected lean meat yield in sheep. Increasing lean meat is due to, the role of betaine as a methyl donor. As a methyl donor, betaine is associated with lipid metabolism via the synthesis of methylated compounds such as carnitine and creatine which in turn decrease the carcass fat deposition (Zhan *et al*., 2006). Also, in the current study, betaine significantly increased the weight of carcass parts but did not affect body fat storages (best rib fat, kidney fat, tail fat, omental and caul fat). Moreover, Siljander-Rasi *et al*. (2003) explained that the heavier carcasses of the betaine group without affecting carcass fatness is due to the lipotropic effect of betaine. The reduction of carcass fat by dietary betaine had been reviewed by several studies in sheep (Fernández *et al*., 1998) and pigs (Zhiguo *et al*., 2011; Lothong *et al*., 2016). The lipotropic effect of betaine resulted in a higher carcass weight without significant effects in carcass fat. Consequently, in the current study, betaine significantly ($P<0.05$) increased the cooking loss of *longissimus dorsi* muscle. The reduction of muscles fat content is associated with high meat water content in bulls (Grosse *et al*., 1991). High water and low fat content of muscles resulted high cooking loss (Hornick *et al*. 1998).

However, betaine slightly increased the dressing percentage. Similarly, Fernández *et al.* (2000) found that dietary betaine (2 g/kg of diet) did not affect the dressing percentage of lambs. In addition, Yu *et al.* (2004) found that dietary betaine at 1.5 g/kg of diet did not affect the dressing percentage in growing pigs.

According to the current research, betaine did not affect the water holding capacity and pH of meat. The present results agree with Yu *et al.* (2004) who showed that dietary betaine (1.5 g/kg of diet) did not affect the water holding capacity of *longissimus dorsi* muscle in pigs. Likewise, Martins *et al.* (2012) found that dietary betaine (1 g/kg of diet) did not affect the pH of pigs' carcass muscles.

CONCLOSIN

The cureent study showed that consuming saline water has deleterious effects on carcass characteristics and meat quality. On the other hand, betaine supplementation improves all carcass characteristics and meat quality treats. When the two factores are studied together in factorial arrangmnt, betaine ameliorates the deleterious effects of saline water consumption on carcass characteristics and meat quality of growing lambs. The amelioration effect of betain in the current study was low and this may be because high level of salt and/or law level of betainewe used.

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تأثير إضافة البيتايين على التأثيرات الضارة للماء المالح وأثر ذلك على صفات ذبيحة وجودة لحوم الحملان

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أجريت الدراسة الحالية بغرض دراسة تأثير إضافة البيتايين في علائق الحملان النامية والتي تستهلك المياه المالحه بغرض معرفة مدى قدرة البيتايين على التخفيف من الأثار الضاره لشرب الماء المالح على مواصفات الذبيحة وجودة اللحوم. تم استخدام عشرون من الحملان النامية من النوع الاوسيمي تتراوح أعمارها تسعة شهور ومتوسط اوزانها ٣١.٥ كجم. استمرة الدراسة لمدة ٥ شهورتم خلالها اضافة مستويين من الملح الى ماء الشرب وهما الماء الجاري (صفر جم ملح/لتر) او الماء المالح (١٥ جم ملح الطعام/لتر) كما تم اضافة البيتايين للعلائق بمستويين ٠ ملجم أو ٢٥٠٠ ملجم /كجم من العليقة لتكتمل الاربع مجاميع للمعاملات كالتالي: المجموعة الضابطه (S0B0) ومجموعة الماء المالح (S1B0)ومجموعة البيايين(S0B1) ومجموعة الماء المالح والبيتايين(S1B1). في نهاية فترة التجربه تم اختيار ثلاث من الحملان من كل مجموعه بحيثتمثل متوسط المجموعه وتم ذبحها بعد تصويمها لمدة ١٢ ساعه وبعد الذبح تم مباشرة تقدير وزن الذبيحة والأعضاء الداخلية كما تم اخذ القياسات على الذبيحة وتقدير وزن ونسب قطعيات الذبيحة. كما تم فصل ثلاث عضلات ممثلة للذبيحة وهي semimembranosus muscle و*longissimus dorsi* muscle وsupraspinatus muscle وتم وزنها وتقدير صفات جودة الذبيحة بها (قدرة الاحتفاظ بالماء – والفقد أثناء لطهي – وقيمة pH اللحم). وكانت أهم النتائج التي تم الحصول عليها ان استهلاك الماء المالح أدي الى انخفاض ($P<0.01$)وزن الحملان النهائي ووزن الذبيحة ووزن الجسم الفارغ كما ادى الي انخفاض($P<0.01$) في وزن الكبد بالاضافة الى أن استهلاك الماء المالح ادى الى انخفاض في وزن قطعيات الذبيحة ولكنه لم يؤثر على نسب هذه القطعيات ما عدا انخفاض($P<0.01$) نسبة loin. وعلى العكس فان اضافة البيتايين في علائق الحيوانات بمعدل (٢٥٠ ملجم/ كجم من المركزات) أدى الى زيادة ($P<0.01$)في وزن الحيوانات النهائي ووزن الحيوانات الفارغ وكذلك وزن الذبيحة بالاضافة الى زيادة ($P<0.05$)وزن الاعضاء الداخلية. كما ان اضافة البيتايين الى علائق الحملان ادي الي زيادة كبيره في وزن قطعيات الذبيحة واثر على بعض نسب مكونات الذبيحة. لم يؤثر أيٍّ من الماء المالح او اضافات البيتايين على صفات جودة اللحوم ولكن التأثير الوحيد كان للبيتايين حيث انه ادى الى زيادة الفقد في عضلة *longissimus dorsi*.