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Chemical Composition of Saline Sources as Suppliers of Minerals for Ruminants

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Abstract

This study aimed to evaluate the mineral composition of solid residues (SR) from desalination waste (DWSR), saline water (SWSR) and aquaculture ponds (APSR), and to discuss the results based on ruminant requirements. Mineral determined were K, P, Ca, Mg, S, Cu, Fe, Mn, Zn, Na, Cl, Ni, Pb, Cd and Cr, from 24 samples, 4 DWSR, 10 SWSR and 10 APSR, with three replicates. Desalination waste solid residue, SWSR and APSR had large variation of minerals. Saline water solid residue and DWSR presented potential to be used as source of Na and Cl, while the APSR can contribute Ca. All examined saline sources were poor in P, Ca and trace minerals except the APSR, showing a considerable concentration of Ca. Some samples of SWSR and APSR presented mineral concentrations that may be potentially toxic to ruminants.

Keywords: animal watering, desalination brine, water quality

1. Introduction

The literature emphasizes the need of minerals for grazing and feedlot ruminants such as cattle, goats and sheep and also their deficiency, which may promote nutritional (Herdt & Hoff, 2011), reproductive (Mendonça Junior et al., 2011) and productive disorders (Tokarnia et al., 1999).

The Brazilian semi-arid presents mineral sources currently regarded as environmental pollutants, which may be evaluated as sources to mineral mix, as is the case of solid residues from desalination waste, aquaculture ponds and saline water (Manera et al., 2014).

The dumping of desalination waste directly in the soil may promote environmental implications (Amorim et al., 2004a; Xu et al., 2013), it is important, then, to search for alternative methods to waste disposal. On the other hand, these saline sources may provide ingredients and raw materials for animal supplementation and contribute to their destination.

According to Xu et al. (2013), the desalination waste shows potential to be used for different purposes. In addition, evaporation and crystallization are strategies to reduce the amount of effluents to obtain solid residues (Amorim et al., 2000; Porto et al., 2001). Kim (2011) also points out effluent evaporation as one of the cheapest method to recuperate salts.

However, little is known about the characteristics of solid residues from desalination waste, saline water and aquaculture ponds, especially on their physic-chemical compositions. This information may be useful to understand their potential as minerals sources for ruminants.

Thus, this study aimed to evaluate the mineral composition of solid residues from desalination waste, saline water and aquaculture ponds and discuss the results based on ruminant requirements.

2. Material and Methods

This study lasted from March 2011 to March 2012. We collected ten samples of solid residues from aquaculture ponds, ten from saline water and four samples of desalination waste, totaling 24 samples, with three replicates. Desalination waste and solid residues from aquaculture ponds were collected in Petrolina-PE, Tauá-CE and Santa Brigida-BA, Brazil. Saline water samples were collected in the municipalities of Jaguarari, Santa Brígida and Pintadas, in Bahia State; Lagoa Grande and Petrolina, in Pernambuco State; and Tauá, in Ceará State, Brazil.

Water samples and desalination waste were stored in labeled plastic bottles, sent to the Laboratory of Animal Nutrition and kept in a freezer until the moment for chemical analyses.

Approximately 25 L of saline water and desalination waste were distributed in plastic trays and placed in a forced air-circulation oven at 55 ºC until the water evaporated. The accumulated solid residue was collected, sampled, stored in collection-type plastic jars and analyzed for the chemical properties. Solid residues from saline and desalination waste were named SWSR and DWSR, respectively.

The solid residue from aquaculture ponds (APSR) were collected directly from the ponds, after fish harvesting operations. Samples were stored and dried in a forced air-circulation oven at 55 ºC until they generated the dry residue.

All samples had their mineral compositions determined at the Soil Laboratory of Embrapa Semiárido. The concentrations of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), chlorine (Cl), nickel (Ni), lead (Pb), cadmium (Cd) and chromium (Cr) were determined according to the methodologies described by Nogueira et al. (2005).

The determination of mineral levels in APSR, SWSR and DWSR followed the same methodology. For this purpose, 10 g of sample were solubilized in 150 mL deionized water. Mineral levels were determined as g or mg/L and then converted to g or mg/kg for SWSR and DWSR.

Sodium and potassium were determined by photometry, whereas Ca and Mg were analyzed by titration, determining the Ca contents and subsequently the Ca + Mg, defining the Mg concentration as the difference. Chlorine and sulfur were determined indirectly, by first obtaining the chlorine and sulfate concentrations and considering their molecular weight, the S and Cl concentrations were determined.

Phosphorus was determined using molecular spectrophotometer and the determination of Cu, Fe, Mn, Zn, Ni, Pb, Cd and Cr was performed on an atomic absorption spectrophotometer (model Analyst 100, Perkin Elmer®). The data were presented as descriptive statistics (means and standard deviations).

3. Results and Discussion

On average, Na levels in the DWSR and SWSR were 508.08 g/kg and 412.09 g/kg, respectively. A smaller average was observed for APSR (5.11 g/kg). The Cl showed the greatest concentration (over 400 g/kg) in the DWSR and SWSR and low levels in the APSR (Table 1). The concentrations of P, K, Ca, Mg and S in the three types of solid residue were low (Table 1). The highest P and K levels were 5.64 g/kg and 19.61 g/kg, respectively, equivalent to 0.056% and 1.99%, both in the APSR.

The highest average of P was found in the APSR (3.07 g/kg), possibly due to the fish ration supply, increasing this mineral in the solid residue. However, in general, the P levels were low, adding a small contribution potential to the animal. The bicalcium phosphate, a traditional P source with 18% of this mineral has a high bioavailability.

In Brazil, phosphorus concentration in the soil and pasture is low (Peixoto et al., 2005), therefore this mineral occupies an elevated proportion in the mineral mix for ruminants (Malafaia et al., 2014). Phosphorus can cause environmental contamination (Castillo et al., 2013), which can be supplemented to the animal in different ways (water, food) (Karn, 2001) and its deficiency can cause ossuary disorders and weakness (Prasad et al., 2015).

Powder supplements are mostly used in Brazil for mineral supplementation of domestic ruminants and are considered a low cost method. The dehydration of desalination waste by evaporation or crystallization tanks may constitute a potential method to include the residues in the animal diets and as destination of possible contaminants.

Amorim et al. (2000) used crystallization tanks and observed 36.06 kg of salts from 5.000 L of brine from desalting, equivalent to 7.21 g/L. Out of the total solid residues obtained, 79.03% corresponded to NaCl, 8.67% of $MgCl_2$, 4.99% of $CaSO_4$, 4.72% of $MgSO_4$ and 2.45% of $CaCl_2$, having potential for industrial use and/or for animal feeding. Xu et al. (2013) reported that several chemical compounds could be obtained from the desalination waste for different purposes.

Evaporation is a potential strategy aimed to disposal the desalination waste (Porto et al., 2001) and the evaporation tanks have been adopted in some countries, especially in localities with high insolation and availability of lands at low cost. However, this strategy may lead to an increase in the concentration of minerals such as selenium, boron and heavy metals, reaching potentially toxic levels (Soares et al., 2006). Amorim et al. (2004b) also pointed out the use of solar evaporation as a tool to improve the handling of residues. The procedure of crystallized salts is the result of water evaporation by salts precipitation. Economically valuable products from these residues may be important to the desalination process which can be influenced by the procedure method, generally selective to a particular product, increasing production costs (Shahmansouri et al., 2015). In the current study the procedure method was non-selective and contained a set of mineral elements, which may have an important advantage.

In the current study, high presence of Na and Cl in the SWSR and DWSR suggest that NaCl is the main salt in these sources. When it comes to the level of Ca, the content in the DWSR was, on average, 37 g/kg, however, one of the samples showed 89 g/kg. The concentration observed in the monocalcium phosphate used in the elaboration of mineral mix is 159 g/kg, higher than presented in the DWSR. One SWSR showed 16.02% of Ca and one APSR had 12.00%, which are close to the levels of monocalcium and bicalcium phosphate. However, it should be noted that the mono and bicalcium phosphates present high bioavailability of Ca.

Table 1. Macro minerals concentrations (g/kg) in salts samples obtained from saline water (SWSR), aquaculture ponds (APSR) and desalination waste (DWSR)

Sample	P	K	Ca	Mg	S	Na	Cl
SWSR							
1	1.27	4.68	124.20	79.39	13.88	322.00	405.90
2	0.98	3.67	76.00	69.11	20.47	276.00	407.68
3	2.66	2.26	80.00	57.03	20.02	460.00	400.59
4	3.63	2.11	76.20	46.85	20.21	460.00	393.50
5	1.70	1.01	108.36	79.17	15.62	391.00	451.99
6	1.41	4.68	60.12	41.33	18.53	506.00	421.50
7	1.27	1.17	104.76	80.85	15.27	368.00	356.27
8	1.63	4.99	80.00	65.80	19.45	414.00	434.26
9	2.56	4.84	160.24	60.17	14.98	230.00	384.63
10	1.27	5.85	53.47	58.25	28.75	483.05	467.99
11	2.35	2.46	28.92	31.09	31.51	414.04	292.49
12	1.27	0.78	1.68	44.78	20.28	621.00	412.99
Mean	1.83	3.21	79.50	59.49	19.91	412.09	402.48
SD	0.76	1.71	40.50	15.52	5.13	101.77	43.68
APSR							
1	2.89	0.29	29.50	1.63	4.50	0.94	0.02
2	5.64	19.61	29.25	1.50	3.35	1.60	0.03
3	3.92	3.70	52.50	2.95	3.33	1.66	0.05
4	4.57	3.09	63.50	3.15	5.58	14.46	0.03
5	0.94	0.57	106.00	2.35	7.50	3.96	0.00
6	3.79	0.57	101.00	2.00	8.83	4.81	0.01
7	1.93	0.57	95.35	1.65	5.38	6.01	0.01
8	2.76	0.57	99.00	1.30	5.42	4.67	0.01
9	2.87	1.58	98.50	3.35	7.97	9.39	0.01
10	1.37	0.57	120.00	2.70	8.00	3.65	0.00
Mean	3.07	3.11	79.46	2.26	5.98	5.11	0.02
SD	1.45	5.92	33.01	0.75	1.98	4.11	0.02
DWSR							
1	3.46	0.94	15.50	20.11	19.02	690.00	298.67
2	2.45	3.20	21.78	27.68	19.48	563.50	458.19
3	1.27	5.15	89.20	69.18	18.53	368.00	450.22
4	3.28	4.21	21.48	165.51	22.71	414.00	485.67
Mean	2.62	3.37	36.99	70.62	19.94	508.88	423.18
SD	1.00	1.81	34.93	66.84	1.89	146.78	84.39

Note: Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; S = sulfur; Cl = chlorine; P = phosphorus; SD = standard deviation.

The differences in composition among samples of APSR for Ca, ranging from 29.25 to 120.00 g/kg, is probably due to the composition of the desalination waste that filled the pond, but may also be justified by the amount of feed supplied or by the concentration of nutrients in the ration. Calcium is the main structural component of bones and teeth and its deficiency can cause rickets, osteomalacia and milk fever (NRC, 2001). However, an excess of Ca can cause hypercalcemia or calcification of body tissues (McDowell, 1989), where 1.50% of DM is pointed as the maximum level in the diet (NRC, 2005).

The Ca:P ratio was high, on average 43.44:1, 25.88:1 and 14.12:1 for SWSR, APSR and DWSR, respectively. The same Ca:P ratio was found for the vast majority of analyzed samples, which may lead to a nutritional imbalance and affect mineral absorption. The 2:1 Ca:P ratio is recommended at the NRC (2007). In Brazilian legislation on mineral mix for bovines, Ca:P ratio of 1:1 of up to 7:1 can be accepted (MAPA, 2004).

The average concentrations of Mg were low, being 5.95%, 0.023% and 7.06% for SWSR, APSR and DWSR, respectively. Traditional Mg sources as magnesium sulfate present 20% of this mineral and magnesium carbonate and magnesium oxide present 31% and 55% of Mg, respectively. One DWSR showed 16.55% of Mg, which is expressive because it approximates to the levels found in magnesium sulfate. A high level of Mg in the diet may restrict feed intake and cause diarrhea, which may also affect the absorption of other elements such as P (NRC, 2001). Levels of Mg above 0.60% of DM are considered as the maximum tolerable, promoting intoxication, urothiliasis and reducing the productive performance (NRC, 2007). Amorim et al. (2004b) reported predominant occurrence of sodium but also magnesium in the desalination salts.

The mineral variation found in all solid residues showed heterogeneous composition, even those in the same group (SWSR, DWSR and APSR), which can be attributed to a series of factors, such as its origin and the water desalination procedures.

Potassium and S levels were low in the examined residues, especially for K. Desalination waste solid residue, SWSR and APSR showed similar average compared to K (3.11 to 3.37 g/kg), which was also observed in the SWSR and DWSR for S, presenting 19.91 and 19.94 g/kg, respectively, while the APSR showed 5.98 g/kg. Potassium deficiency can cause a reduction in growth, productive performance and feed intake (PULS, 1994). Potassium is an element to be considered in the prenatal stage, when supplementation of anionic diets can be a strategy to reduce the incidence of metabolic and nutritional disorders (Wilkens et al., 2012).

Both Na and Cl showed low levels in the APSR, and this can be attributed to the hydric circulation of the ponds. The APSR receives the brine from desalting and it shows a daily renewal to maintain a favorable aquatic environment. In this way, the brine that leaves the tank may contain a high salt concentration, especially Na and Cl.

The concentrations of Na and Cl in the SWSR and DWSR may constitute these residues as alternatives sources of Na and Cl. Desalination waste solid residue had, on average, 79.5 g/kg Ca, which may reduce the inclusion of traditional NaCl source by 15% in the mineral mix for sheep. Although they were found at low amount, Mg, K, S and P averaged 59.49, 3.21, 19.91 and 1.83 g/kg, respectively, and should not be discounted as mineral suppliers.

The replacing of NaCl by SWSR may represent a reduction in the production costs, since the SWSR can be obtained at lower costs, but the main purpose of the inclusion of solid residues as SWSR and DWSR is the reduction in the environmental damage. The mineral profile of DWSR reflected the chemical composition of the waste itself, showing higher prevalence of Na and Cl.

Sodium deficiency is one of the most important deficiencies among ruminants throughout the world since there is a shortage of Na in pastures in all continents. However, chlorine deficiency in ruminants is much more difficult to occur (Tokarnia et al., 2000). Sodium chloride is seen as a universally safe and cheap supplement for ruminants with important functions such as the acid-base balance, water metabolism and control of osmotic pressure. Sodium chloride can be considered attractive for the mineral mix intake by the animal, but also exerts a limitation on intake when given in excess. An adult bovine ingests about 30 to 35 g of NaCl daily (Tokarnia et al., 2000; Peixoto et al., 2005).

The two main sources of Na as mineral supplements for ruminants are sodium chloride and sodium bicarbonate, with 400 g/kg and 270 g/kg of sodium, respectively. The SWSR, DWSR and APSR showed 412.09 g/kg, 508.88 g/kg and 51.10 g/kg, on average, respectively. High Na levels for the SWSR and DWSR are indicative of these solid residues as potential sources for mineral supplements.

According to NRC (2005) it is described that toxicity to NaCl is observed from the intake of over 4.0% of DM, or 25.20 g/day for animal with intake of 630 g/day of DM. In addition, the low levels of P, K, Ca and Mg in relation to the traditional mineral sources suggest low intoxication potential.

The smallest macro minerals concentrations in the APSR in comparison to SWSR and DWSR suggest high level of organic matter and nitrogen in the APSR, possibly due to the fish feed or because of presence of impurities. Amorim et al. (2004b) reported that the presence of impurities is one of the factors compromising its use.

The Cu, Mn, Zn and Ni levels were low in the three examined residues (Table 2). The APSR showed the highest average of these four elements and of the total trace minerals. Furthermore, a heterogeneous concentration of trace mineral was observed in the three types of residues, which Mn, for example, was 1.83 mg/kg, 34.78 mg/kg and 192.90 mg/kg, respectively in SWSR, DWSR and APSR. Just as the heterogeneity in mineral concentration, in the same type of residue, Zn showed a concentration of 0.30 mg/kg to 8.50 mg/kg in SWSR and 71.25 to 325 mg/kg in DWSR.

The highest average of Cu was found in the APSR with 16.9 mg/kg. The other two groups of residues presented values below 0.40 mg/kg. Copper sources to mineral mix for ruminants, such as copper sulfate shows 25% of this mineral, while copper oxide may reach up to 75% of Cu. Copper plays an important role for the enzymatic systems and its deficiency is associated with anemia (NRC, 2005). Mohammed et al. (2014) reported that Cu is one of the limiting minerals for ruminants in pastures in Asia, Africa and Latin America and its deficiency may promote reduction in growth, ossuary disorders, diarrhea and infertility.

Manera (2013) studied the Cu concentration in commercial mineral mix for lambs in Brazil and reported average of 463 mg/kg, ranging from 200 to 800 mg/kg. Considering the amount of 10 g/day of the mineral mix in daily intake containing 463 mg/kg of Cu, ingestion would be 4.63 mg/day. The maximum tolerable level of Cu for ovines is 15 mg/kg of DM when normal concentration of Mo and S are offered. Copper is one of the main minerals associated with intoxication of ruminants, especially in sheep, but levels found in solid residues were low and represent low intoxication potential to ruminants.

The sources normally used to supply Mn in the mineral mix are manganese sulfate and magnesium carbonate, with 30% and 46% of Mn, respectively. Manganese is an essential element to the animal's metabolism (Pitropvska et al., 2014), in the formation of the organic bone matrix (Zhang et al., 2014) and as a component of several enzymes that are involved in many processes of the organism (Khan et al., 2015). According to NRC (2007) the Mn is not toxic to ruminants even at high levels, but an excess can affect the absorption of Fe. In the NRC (2005), the maximum tolerable level of Mn is 2.000 mg/kg of DM.

The Zn sulfate contains 36% and oxide contains 72% of this mineral. Both for Mn and Zn, the levels observed in the residues are below the ones which traditional sources are able to supply. The APSR showed on average 192.0 mg/kg of Mn with one of the samples containing 972 mg/kg, the most expressive of all the examined residues. Zinc is part of the composition of many enzymes of several metabolic pathways and its deficiency can cause reproductive and skeletal disorders, skin and wool anomalies and anorexia (NRC, 2007). Ruminants can tolerate a larger intake of Zn than non-ruminants. For lambs the maximum tolerable level is 300 mg/kg of MS (NRC, 2005).

Table 2. Concentration of microminerals (mg/kg) in residues samples obtained from saline water (SWSR), aquaculture ponds (APSR) and desalination waste (DWSR)

Sample	Cu	Fe	Mn	Zn	Ni	Cd	Pb	Cr
SWSR								
1	0.20	2.00	0.40	0.42	1.70	0.14	5.50	0.91
2	0.43	17.50	0.40	0.50	0.40	0.26	5.00	1.25
3	0.26	10.00	0.19	0.70	1.50	0.17	2.51	1.25
4	0.23	3.85	0.50	0.35	0.00	0.00	0.35	0.81
5	0.26	2.40	0.50	1.00	0.00	0.06	0.00	0.65
6	0.28	17.00	0.35	8.50	0.00	2.00	0.00	0.35
7	0.45	2.00	0.50	0.50	1.00	0.07	6.00	0.55
8	0.44	9.45	0.67	0.30	1.21	0.14	0.56	0.05
9	0.45	3.80	1.37	0.53	0.66	0.50	0.84	0.30
10	0.55	9.30	0.88	0.49	0.00	0.00	0.00	0.00
11	0.47	8.48	15.75	2.25	0.00	0.00	1.80	1.05
12	0.20	4.50	0.50	0.45	0.15	0.02	1.51	0.73
Mean	0.35	7.52	1.83	1.33	0.55	0.28	2.00	0.66
SD	0.12	5.22	4.21	2.22	0.62	0.54	2.16	0.41
APSR								
1	29.0	231.5	80.7	300.0	47.3	5.8	57.3	20.2
2	31.0	397.5	88.6	245.0	54.6	3.0	82.3	66.9
3	16.5	274.0	302.0	145.0	40.7	3.4	25.7	0.0
4	21.5	3,120.0	82.0	215.0	47.7	5.8	74.0	73.5
5	8.0	1,385.0	49.2	195.0	46.0	5.7	22.4	10.7
6	14.0	1,280.0	111.0	150.0	39.7	6.8	32.3	7.5
7	16.0	1,170.0	95.1	215.0	38.5	9.7	22.9	5.4
8	10.5	740.0	99.4	125.0	45.5	9.8	22.9	19.5
9	15.0	2,215.0	972.0	345.0	38.3	0.0	41.0	30.0
10	8.0	1,600.0	49.4	320.0	41.0	5.0	28.1	10.6
Mean	16.9	1,241.3	192.9	225.5	43.9	5.5	40.9	24.4
SD	8.0	916	283.0	76.4	5.2	3.0	22.4	25.6
DWSR								
1	0.37	6.48	32.38	161.88	0.32	0.24	0.00	0.00
2	0.18	5.50	27.50	137.50	0.13	0.03	0.30	0.51
3	0.27	2.85	14.25	71.25	0.33	0.23	0.00	0.00
4	0.72	13.00	65.00	325.00	1.50	0.08	0.91	0.41
Mean	0.39	6.96	34.78	173.91	0.57	0.15	0.30	0.23
SD	0.24	4.31	21.55	107.76	0.63	0.11	0.43	0.27

Note: Cu = copper, Fe = iron, Mn = manganese, Zn = zinc, Ni = nickel, Pb = Lead, Cd = Cadmium, Cr = chromium, SD = standard deviation.

Manera (2013) reported an average inclusion of 1.688 mg/kg of Fe in the mineral supplements for lambs, ranging from 400 to 2.200 mg/kg. In the SWSR and DWSR, Fe levels were low, presenting 7.52 and 6.96 mg/kg, respectively. However, in the APSR the average was 1.243 mg/kg with a sample attaining 3.120 mg/kg, representing the baseline or above the levels reported by Manera (2013). Iron sources for ruminant mineral mix such as ferrous sulfate heptahydrate and ferrous carbonate showed 200 g/kg and 380 g/kg, respectively.

Tokarnia et al. (2000) and Peixoto et al. (2005) reported that there is an excess of Fe in mineral supplements for grazing ruminants in Brazil and several regions of the world. Forage and soil intake already supplies the amount of Fe to the animal. In this case, the presence of Fe in the mineral mix can be an anti-economic factor, raising the production cost. According to NRC (2007) an excess of free Fe can cause oxidative membrane damage and high level of this element can promote Cu deficiency in goats and sheep. The NRC (2005) suggests 500 mg/kg of DM as the maximum limit.

Nickel is required in small amount by the animal and the NRC (2005) describes that 100 mg/kg is the maximum tolerable level for bovines. Nickel levels observed in SWSR and DWSR were below the maximum levels described for bovines. In the APSR, the average concentration of Ni was 43.9 mg/kg with one sample containing 54.6 mg/kg. When reviewing the mineral elements and the nutrient levels of the mineral mix for lambs in Brazil, Manera (2013) related that Ni was included in only one mineral supplement with a concentration of 20 mg/kg.

Chrome was obtained in small concentrations in the three solid residues. The highest average was observed in the APSR. The trivalent form of this element is not considered toxic, while the hexavalent form is associated with membrane damage. Chrome and nickel are elements required by animals, in which chrome is associated with stress responses, glucose metabolism and immune response, while nickel is required for the ruminant microorganisms (NRC, 2007). In the NRC (1980), it is recommended the value of 1.0 mg/kg as the maximum limit for Cr. Considering this concentration, three SWSR and nine APSR would be restrictive to their use. Gomes et al. (2013) found elevated levels of Cr, above 1.0 mg/kg in mineral supplements for dairy cattle and justified these concentrations by the inclusion of natural rocks in the mineral mix.

Cadmium and Pb were identified in most samples of the examined residues. The mean concentrations of Cd were 0.28; 5.50 and 0.15 mg/kg in the SWSR, APSR and DWSR, respectively. However, for Pb, the averages were 2.0, 40.9 and 0.30 mg/kg, respectively. The highest levels of Pb and Cd were 82.30 mg and 9.80 in the APSR, respectively. However, these results suggest possible contamination in aquaculture ponds because the water and the desalination waste presented low concentrations of Ca and Pb.

Cadmium and Pb are considered toxic to animals. Cadmium is associated with renal damage (NRC, 2001) and Pb can cause hematologic, reproductive, immune, vascular and renal damage (Pareja-Carrera et al., 2014). They are also antagonistic to other minerals. Cadmium interferes in the absorption and metabolism of Zn and Cu, as Pb affects the absorption and function of Zn (NRC, 2001) and metabolism of Ca (Pareja-Carrera et al., 2014). In addition, Ca, P, Fe and Zn can reduce the absorption of Pb by the animal (NRC, 2001).

The AAFCOI (2001) recommends 0.5 mg/kg and 30 mg/kg for Cd and Pb as maximum content, respectively. Then, one SWSR and nine APSR showed Cd levels above the recommendation. In the case of Pb, all SWSR and DWSR showed concentrations below 30 mg/kg, while for APSR in five of the ten the concentrations were above this limit.

Maletto (1986) suggested the amount of 10 mg/kg as the maximum level for Pb, which would restrict all APSR samples, where the lowest value found was 22.4 mg/kg. On the other hand, the SWSR and DWSR remained below the maximum level, although, in three SWSR samples and in two DWSR the presence of Pb was not observed.

Marçal et al. (2005) also observed Pb levels above 30 mg/kg in commercial mineral mix for bovines in Brazil. Similarly, Marçal et al. (2003) examined the levels of Cd, Pb and other heavy metals in phosphate sources to be used in mineral supplements and they observed contamination by xenobiotics, except for bicalcium phosphate. In the case of Cd, some samples (phosphate rocks) showed levels exceeding 0.5 mg/kg, the limit suggested by AAFCOI (2001), while for Pb the levels observed were below the recommended.

The SWSR and DWSR showed potential as source of NaCl and contributed to other mineral to a lesser degree. The macrominerals showed concentrations that were not potentially toxic to the animals and should be considered in the mineral nutrition in order to avoid imbalances and antagonism. Iron was found in high concentrations in a part of the samples, which can affect other mineral elements, while Mn, Zn, Cu and Ni showed low levels. The concentrations of Cr, Pb and Cd were found to be the most restrictive factors for the use of the residues for mineral mix, presenting concentrations that exceeded the safe levels.

Manera et al. (2014) included 20% of APSR in mineral mix for lambs and observed that mineral and feed intakes, as well as water intake, were similar for animals receiving commercial supplement compared to those consuming the mineral supplement made from APSR. The hydric balance and the dry matter digestibility were not affected by mineral supplements (Manera et al., 2014), which is an indicative of the possibility to include this solid residue in mineral mix for lambs. However, additional research is needed to better understand the response of the animals to these sources, apart from the examination of the economic viability of the process.

4. Conclusions

The examined saline residues from aquaculture ponds (APSR), saline water (SWSR) and desalination waste (DWSR) presented large variation in mineral elements. The SWSR and DWSR presented potential as sources of Na and Cl, while the APSR can contribute with Ca. All examined saline sources were poor in P and Ca and trace minerals except for the APSR, which displayed a reasonable concentration of Ca. Some samples of SWSR and APSR presented heavy mineral levels that can be potentially toxic to ruminants.

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