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Influence of the addition of KCl and $CaCl_2$ blends on the physicochemical parameters of salted meat products throughout the processing steps

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Abstract

The objective of this study was to evaluate the effects of different chloride salts (NaCl, KCl, and CaCl2) on the characteristics of salted meat products through the determination of moisture, pH, aw, chloride, ash levels, cooking loss, and instrumental color during the processing steps. Four salted meat treatments were elaborate using the following salts in the wet and dry salting steps: FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 25% CaCl2; F3: 50% NaCl + 25% KCl + 25% CaCl2. The addition of CaCl2 led to the lowest pH and changes in aw, moisture, ash levels, and instrumental color when compared to the other treatments, which was different from the control (100% NaCl) and F1 (50% NaCl + 50% KCl), thus evidencing the great effect of CaCl2 on the characteristics of salted meat products during the whole processing. The partial replacement of NaCl by KCl and/or CaCl2 greatly increased the cooking loss of salted meat products. The replacement of NaCl by KCl promoted similar quality parameters.

Keywords: salted meat; sodium reduction; potassium chloride; calcium chloride.

Pratical Application: Use of KCl and $CaCl_2$ as a strategy to reduce sodium content in salted meat.

1. Introduction

Salted meat products are consumed and appreciated worldwide due to their unique sensory characteristics and long shelf-life (Liu et al., 2014). The manufacture of salted meat products is based on the hurdle technology (Leistner, 1987), and several steps such as salting (wet or dry), drying and ripening can be used during processing (Mora et al., 2015), besides the addition of sodium chloride (NaCl) and additives, and vacuum packaging (Shimokomaki et al., 1998). The combination of these steps provides the sensory characteristics and microbiological stability for the processed product (Ishihara et al., 2013).

Changes in lifestyle associated with the modernization of society and the development of new products have led to a drastic change in eating habits, with increased consumption of processed products. Some of these products can be a major source of fat, sodium, and sugars, which can cause various health problems when consumed in excess, such as obesity, diabetes, and cardiovascular disorders (Roberfroid, 2002). Therefore, there is a growing consumer's demand for healthy eating perceptions and healthy lifestyle, with a preference for meat products rich in proteins and low in lipids, cholesterol and sodium (Lorenzo & Carballo, 2015).

Sodium chloride is an ingredient extensively used and very important to the development of numerous desirable sensory and technological characteristics in meat products (Inguglia et al., 2017). It plays an important role in salted meat products, once when combined with other techniques, it can preserve the product for months without refrigeration for later consumption (Torres et al., 1989). However, NaCl is the main source of sodium in the human diet (Desmond, 2006), and the excessive sodium intake causes several deleterious health effects such as high blood pressure, cardiovascular and renal diseases (Cook et al., 2016; Denton et al., 1995; Frieden, 2016; Strazzullo et al., 2009). The World Health Organization (WHO) recommends a daily intake of 2 g of sodium, equivalent to 5 g NaCl. In this context, an effective reduction of NaCl during the manufacture of salted meat product, which presents a high sodium content after processing, is extremely necessary to make the product healthier.

There are many ways to reduce sodium content in meat products. One of the most used strategies for reducing or replacing NaCl is the use of other chloride salts as KCl (potassium chloride), $CaCl_2$ (calcium chloride) and $MgCl_2$ (magnesium chloride) (Aliño et al., 2010; Ripollés et al., 2011). Among the chloride salts, KCl is widely used due to the development of similar characteristics to NaCl in meat products; however, the addition of KCl promotes bitter and metallic taste, thus impairing the use in excess (Doyle & Glass, 2010; Grummer et al., 2013). Although $CaCl_2$ is also used as a substitute for NaCl, in some cases it can negatively affect the texture and flavor characteristics (Vidal et al., 2019).

Taking into account the deleterious health effects caused by the excessive consumption of sodium in salted meat products, the objective of this study is to evaluate the effects of blends containing NaCl, KCl, and $CaCl_2$ on the characteristics of salted meat treatments.

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2 Material and methods

2.1 Treatments, raw materials, and additives

The bovine raw meat (*biceps femoris*) was purchased from slaughterhouses with assured hygienic quality. The additives sodium nitrite and sodium erythorbate were donated by the company Kerry of Brazil. The salts NaCl, KCl, and $CaCl_2$ were purchased from Anidrol, Brazil.

Four salted meat treatments were made, as shown in Table 1. The concentration of KCl and $CaCl_2$ substitute salts was based on the calculation of ionic strength to make up the ionic strength of 50% and 25% of NaCl, obtaining the same final ionic strength in all treatments. Then, the blends were made in sufficient quantity for the salting steps, depending on the weight of the raw meat, using 2 kg salt per kg of meat. Similar amounts of the additives sodium nitrite (150 ppm) and sodium erythorbate (500 ppm) were added in the wet salting step, and the salt was the variable of the wet and dry salting steps.

2.2 Processing

The manufacturing process was carried out according to Vidal et al. (2019) and the salts added were described in Table 1. The bovine raw meat pieces have been cut standardized to be submitted to the salting steps (wet and dry). In the wet salting step, the treatment were submerged in a respective saturated solution with respective salts, sodium nitrite and sodium erythorbate for 1 hour. During the dry salting period, the treatments were in contact with respective salts for 144 hours (6 days) at 13 °C. The ripening step were carried out in a controlled climatic chamber (Instala Frio, Curitiba, Brazil) with 55% humidity, 25 °C and 0.5 m/s forced air ventilation for 24 hours. After the process, the pieces were vacuum packed with polyethylene (Spel, São Paulo, Brazil) and stored at 25 °C.

All the manufacture process was performed in three replicates on different days with the same methodology, formulation and technology. All the processing steps were carried out in the Meat Laboratory of the Department of Food Technology (DTA) at University of Campinas (UNICAMP).

2.3 Physicochemical characterization

The chloride content was determined according Doughty (1924) using silver nitrate for reaction and potassium chromate as indicator. The moisture and ash content was determined according to Horwitz & Latimer (2005). The pH was determined by homogenizing 10 g sample and distilled water (1:10), utilizing combined electrode (22 DM, Digimed, São Paulo, Brazil). The water activity (aw) was measured at 20 °C using the Aqualab apparatus (Decagon Devices Inc., Pullman, USA).

The instrumental color was measured using the Hunter Lab colorimeter (Colourquest II, Hunter Associates Laboratory Inc., Virginia, USA) with D65 illuminant, 20 mm aperture and standard 10° observer. CIELAB L*, a*, and b* parameters were determined as an indicator of luminosity, red intensity, and yellow intensity, respectively. The whiteness index (W) was calculated by the following equation: $100 - \left[(100 - L^*)\ 2 + a^*\ 2 + b^*\ 2 \right] 1/2$. The samples were kept at room temperature (25 °C) during analysis.

All analyses were performed in triplicate for each replicate of the experiment.

2.4 Cooking loss

The samples of the different treatments were cut into portions of 6x6 cm and desalted using a ratio of 1:6 (sample:water), with continuous water exchange every 2 hours for 30 hours, and then vacuum packed for cooking. Cooking was carried out in a water bath (RSA-1708, RSA, Campinas, Brazil) at 80°C, and the temperature of the samples was monitored by a thermocouple. From the moment the center of the sample reached 72 ° C, remaining at this temperature for 60 minutes.

After cooking procedure, the cooked samples were weighed after 30 minutes at room temperature. The cooking loss was calculated as a percent of weight difference between raw meat and cooked sample using the following equation: $\text{cooking loss} = (\text{raw sample} - \text{cooked sample} \ / \ \text{raw sample}) \ x \ 100$.

2.5 Statistical analysis

For each process, at least three samples were taken for each analysis. The results were expressed as the averages from all data. Data were analyzed using a General Linear Model (GLM) considering the treatments as a fixed effect and the replicates as a random effect. Significant differences were analyzed by the Tukey's test at the 5% level of significance utilizing the commercial software Statistica v. 8 (Statsoft Inc., Tulsa, Oklahoma, USA).

3 Results and discussion

3.1 Chloride, ash, and moisture contents

The moisture contents are presented in Table 2, chlorides levels in Table 3 and ash in Table 4. There is a relationship among the chloride levels and the ash and moisture contents of the samples.

Table 1. Salts used to performed the salted meat treatments.

Treatments	NaCl (%)	NaCl (mg)*	KCl (%)	KCl (mg)*	$CaCl_2$ (%)	$CaCl^2$ (mg)*
FC1	100	1000	-	-	-	-
F1	50	441	50	560	-	-
F2	50	614	-	-	50	387
F3	50	513	25	326	25	162

The amount of salt added was based on the ionic strength, all treatments obtained the same ionic strength. *Salt proportion added according to ionic strength, for each 1000mg of bovine raw meat was utilized 2000mg of salt.

The treatment F2 (50% NaCl + 50% $CaCl_2$) had the lowest ash ($P < 0.05$) and the highest moisture contents ($P < 0.05$) in the final product when compared to the other treatments. These results may be due to the difficulty of $CaCl_2$ to penetrate into the product, once it was used in excess (equivalent to 50% of ionic strength).$CaCl_2$ is used in several products as a dehydrating agent, once calcium ions increase the mass transfer leading to a higher dehydration rate (Lewicki & Michaluk, 2004). However, the high dehydration may have formed a dry barrier on the surface of the samples, impairing the water release from meat and the penetration of salt (Vidal et al., 2019).

3.2 pH and aw

The results of pH of salted meat treatments are shown in Table 5. In general, a decrease in the pH values was observed during the process. The addition of $CaCl_2$ decreased the pH values when compared to the treatments containing only

Table 2. Moisture (%) in salted meat treatments during process.

Treatments	Raw meat	AWS	ADS	FP	Standard error
FC1	75.15	72.54^{aA}	52.75^{bB}	50.61^{bC}	1.94
F1	75.19^{a}	72.52^{aA}	52.39^{bB}	50.55^{bC}	1.95
F2	75.22^{a}	72.90^{aA}	51.28^{cB}	51.44^{aB}	1.99
F3	75.21^{a}	72.98^{aA}	55.16^{aB}	50.06^{bC}	1.92
Standard error	0.13	0.11	0.24	0.12	

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test ($P < 0.05$). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test ($P < 0.05$). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

Table 3. Chlorides (%) values in salted meat treatments during process.

Treatments	Chlorides				
	Raw meat	AWS	ADS	FP	Standard error
FC1	0.21^{a}	1.86^{cC}	16.44^{aA}	14.53^{abB}	1.29
F1	0.20^{a}	2.34^{bB}	16.76^{aA}	15.56^{aA}	1.31
F2	0.20^{a}	2.39^{abC}	16.41^{aA}	13.23^{bB}	1.19
F3	0.20^{a}	2.54^{aB}	16.37^{aA}	15.28^{aA}	1.27
Standard error	0.01	0.05	0.29	0.28	

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test ($P < 0.05$). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test ($P < 0.05$). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

Table 4. Ash (%) and cooking loss (%) values in salted meat treatments during process.

Treatment	Ash					Cooking Loss
	Raw meat	AWS	ADS	FP	Standard error	
FC1	1.07^{a}	2.66^{cC}	17.93^{bA}	17.32^{cB}	1.23	16.94^{b}
F1	1.04^{a}	3.55^{aC}	19.55^{aA}	18.79^{aB}	1.39	26.67^{a}
F2	1.03^{a}	3.15^{bC}	15.85^{cA}	15.16^{dB}	1.08	25.60^{a}
F3	1.09^{a}	3.48^{aB}	19.22^{aA}	18.99^{aA}	1.34	25.55^{a}
Standard error	0.01	0.07	0.26	0.32		0.78

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test ($P < 0.05$). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test ($P < 0.05$). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

Table 5. pH values in salted meat treatments during process.

Treatment	Raw meat	AWS	1º day	2º day	3º day	4º day	5º day	ADS	FP	Standard error
FC1	5.63^{a}	5.61^{abB}	6.05^{aA}	5.46^{aD}	5.45^{aD}	5.47^{aD}	5.24^{aE}	5.52^{aC}	5.25^{bE}	0.12
F1	5.63^{a}	5.63^{abB}	5.93^{bA}	5.46^{aBC}	5.41^{bCD}	5.38^{bCD}	5.26^{aD}	5.49^{aBC}	5.39^{aCD}	0.08
F2	5.64^{a}	5.42^{bB}	5.83^{cA}	5.40^{bB}	5.28^{cC}	5.16^{cD}	5.17^{bD}	5.31^{bB}	5.13^{cD}	0.05
F3	5.65^{a}	5.73^{aB}	5.88^{bcA}	5.41^{bC}	5.26^{dD}	5.12^{dE}	4.99^{cF}	5.18^{cDE}	5.00^{dF}	0.07
Standard error	0.01	0.09	0.02	0.01	0.01	0.02	0.02	0.12	0.13	

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test ($P < 0.05$). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test ($P < 0.05$). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

NaCl and KCl, once the treatments F2 (50% NaCl + 50% $CaCl_2$) and F3 (50% NaCl + 25% KCl + 25% $CaCl_2$) presented lower pH values when compared to FC1 (100% NaCl) and F1 (50% NaCl + 50% KCl). Other authors have reported the effect of $CaCl_2$ on the pH reduction of meat products with reduced NaCl content (Gimeno et al., 2001; Lawrence et al., 2003; Gimeno et al., 1999; Vidal et al., 2019).

Aw is a very relevant parameter to ensure food safety, and especially in salted meat products, the low aw can confer stability during several months of storage (Toldrá, 2006). As expected, the addition of salts to the treatments significantly reduced the aw values during the process, as shown in Table 6. The treatment F2 (50% NaCl + 50% $CaCl_2$) presented the highest aw values (*P <0.05*) during the dry salting and in the final product. As previously discussed, the higher addition of $CaCl_2$ during the dry salting may have caused a rapid surface drying, impairing the water release in the treatments.

3.3 Instrumental color

The color characteristics of meat and meat products are fundamental for the consumers' acceptance of the product, and myoglobin is the only pigment present in sufficient amount capable of providing red color (Mancini & Hunt, 2005). As can be seen in Table 7, the color parameters L* (luminosity), a* (red-green dimension), b* (yellow-blue dimension) and W (whiteness index) of the treatments were affected by the addition of different salts.

Table 6. Aw values in salted meat treatments during process.

Treatment	Raw meat	AWS	1° day	2° day	3° day	4° day	5° day	ADS	FP	Standard error
FC1	0.988^{a}	0.977^{aA}	0.948^{bB}	0.893^{bC}	0.851^{bD}	0.827^{bE}	0.786^{bF}	0.778^{bG}	0.769^{bH}	0.005
F1	0.989^{a}	0.973^{aA}	0.918^{dB}	0.864^{cC}	0.845^{cD}	0.803^{cE}	0.775^{cF}	0.765^{cG}	0.752^{cH}	0.009
F2	0.988^{a}	0.974^{aA}	0.956^{aB}	0.904^{aC}	0.901^{aC}	0.846^{aD}	0.827^{aE}	0.799^{aF}	0.781^{aG}	0.009
F3	0.989^{a}	0.976^{aA}	0.939^{cB}	0.889^{bC}	0.855^{bD}	0.826^{bE}	0.783^{bF}	0.776^{bG}	0.756^{cH}	0.008
Standard error	0.001	0.001	0.002	0.003	0.004	0.003	0.003	0.002	0.002	

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test (*P < 0.05*). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test (*P < 0.05*). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

Table 7. L* (luminosity), a* (red-green dimension), b* (yellow-blue dimension) e W (whiteness index) values in salted meat treatments during process.

Tr.	Raw meat	AWS	1° day	2° day	3° day	4° day	5° day	ADS	FP	Standard error
L*										
FC1	37.09^{a}	37.61^{aD}	32.07^{bcF}	32.41^{cF}	35.94^{bE}	41.91^{bC}	49.83^{aA}	41.53^{dC}	47.93^{bB}	0.74
F1	37.33^{a}	34.00^{bE}	32.61^{bF}	33.21^{cF}	35.67^{bD}	39.29^{cC}	42.88^{bB}	46.61^{bA}	47.51^{bA}	0.68
F2	37.54^{a}	36.84^{aE}	31.38^{cG}	35.45^{bF}	34.19^{cF}	39.33^{cD}	40.06^{cC}	44.00^{cB}	48.15^{bA}	0.61
F3	36.89^{a}	37.59^{aF}	34.95^{aG}	36.53^{aF}	44.43^{aD}	45.83^{aC}	43.12^{bE}	48.58^{aB}	54.26^{aA}	0.74
Standard error	0.54	0.29	0.25	0.31	0.69	0.47	0.62	0.49	0.50	
a*										
FC1	16.94^{a}	8.80^{cD}	15.23^{dA}	14.58^{aA}	14.44^{aA}	11.89^{aB}	12.34^{aB}	10.53^{aC}	12.03^{aB}	0.25
F1	16.74^{a}	9.87^{bE}	16.21^{cA}	13.61^{bB}	12.08^{bC}	10.66^{bD}	11.76^{aC}	9.78^{bE}	10.36^{bDE}	0.25
F2	16.23^{a}	11.54^{aE}	18.31^{aA}	12.77^{cD}	14.55^{aC}	9.41^{cF}	9.45^{bB}	8.41^{cG}	7.81^{cG}	0.42
F3	16.41^{a}	9.89^{bD}	16.90^{bA}	12.75^{cB}	11.99^{bC}	9.79^{cD}	9.64^{bD}	8.80^{cE}	6.78^{dF}	0.34
Standard error	0.62	0.18	0.20	0.16	0.21	0.18	0.44	0.15	0.37	
b*										
FC1	18.05^{a}	13.79^{aF}	15.66^{aDE}	16.03^{aCD}	15.19^{bE}	16.65^{abBC}	19.12^{aA}	16.39^{bBCD}	17.12^{aB}	0.18
F1	18.39^{a}	12.02^{bE}	14.76^{bCD}	14.51b^{D}	14.31^{cD}	15.89^{bBC}	16.46^{cAB}	17.64^{aA}	16.32^{abBB}	0.21
F2	17.84^{a}	13.24^{aE}	16.05^{aB}	14.22^{bCD}	14.95^{bC}	14.54^{cCD}	17.81^{bA}	13.91^{cDE}	15.72^{bB}	0.17
F3	18.22^{a}	13.15^{aE}	16.23^{aC}	14.93^{bD}	17.28^{aAB}	16.84^{aBC}	15.36^{dD}	17.86^{aA}	15.55^{bD}	0.17
Standard error	0.22	0.14	0.12	0.15	0.19	0.19	0.25	0.30	0.15	
W										
FC1	32.40^{a}	35.50^{aC}	28.65^{bE}	29.02^{dE}	32.60^{bD}	38.41^{bB}	44.91^{aA}	38.36^{cB}	43.86^{cA}	0.69
F1	32.58^{a}	32.18^{bD}	29.14^{bE}	30.31^{cE}	33.00^{bD}	36.34^{cC}	39.40^{bB}	42.91^{bA}	44.05^{cA}	0.64
F2	33.05^{a}	34.43^{aD}	27.18^{cG}	32.68^{bE}	30.96^{cF}	36.91^{cC}	35.45^{cD}	41.69^{bB}	45.26^{bA}	0.65
F3	32.29^{a}	35.46^{aE}	30.85^{aG}	33.56^{aF}	40.59^{aD}	42.43^{aC}	40.29^{bD}	44.85^{aB}	51.21^{aA}	0.73
Standard error	0.37	0.27	0.25	0.32	0.64	0.42	0.58	0.44	0.53	

Values are means. $^{a, b, c, d}$ Means in the same column followed by different lowercase letters present statistically significant difference by the Tukey test (*P < 0.05*). ^{A,B,C,D} Means in the same line followed by different capital letters present statistically significant difference by the Tukey test (*P < 0.05*). AWS: after wet salting; ADS: after dry salting; FP: final product. FC1: 100% NaCl; F1: 50% NaCl + 50% KCl; F2: 50% NaCl + 50% $CaCl_2$; F3: 50% NaCl + 25% KCl + 25% $CaCl_2$.

A lower intensity of red color was observed in the salted meat products (*P <0.05*) with the addition of KCl (F1: 50% NaCl + 50% KCl), which was more pronounced (*P <0.05*) in the treatments with the addition of $CaCl_2$ (F2: 50% NaCl + 50% $CaCl_2$ and F3: 50% NaCl + 25% KCl + 25% $CaCl_2$) in relation to the control made with 100% NaCl (FC1). In addition, the parameter W (whiteness index) increased (*P < 0.05*) in all treatments during the manufacturing process of the salted meat products. Similar results were found by Vidal et al. (2019) who replaced NaCl by KCl and $CaCl_2$ in jerked beef.

3.4 Cooking loss

The heat treatment induces the water loss in meat and meat products, and the determination of this parameter during cooking is very important to predict yielding, the nutritional quality, and the sensory properties of the product, mainly regarding the juiciness perception (Bertram et al., 2003). The cooking loss values are presented in Table 4.

The parcial replacement of NaCl by KCl and $CaCl_2$ increased considerably (*P <0.05*) the cooking loss values. The control treatment (FC1: 100% NaCl) presented 16.94% of cooking loss in relation to the treatments containing NaCl + KCl (F1: 50% NaCl + 50% KCl), NaCl + $CaCl_2$ (F2: 50% NaCl + 50% $CaCl_2$) and NaCl + KCl + $CaCl_2$ (50% NaCl + 25% KCl + 25% $CaCl_2$), which exhibited values from 25.55 to 26.67%, with no significant difference (*P <0.05*) between them. This substitution may have increased the protein denaturation during cooking, with a lower trapping of water molecules within the protein structures maintained by the capillary forces (Aaslyng et al., 2003).

As mentioned, the cooking loss is a very important parameter affecting several characteristics, and the differences in cooking loss around 9% between the control and the treatments with partial replacement of NaCl by salt substitutes can directly affect the quality of the final product.

4 Conclusion

The addition of $CaCl_2$ during the processing of salted meat products significantly affected all the parameters studied when compared to the treatments containing only NaCl (control) or NaCl + KCl, with a consequent impact on product's quality.

The replacement of NaCl by KCl and $CaCl_2$ significantly increased the cooking loss, which may affect the sensory characteristics of the salted meat product. In general, the treatment containing NaCl + KCl presented similar characteristics to the control treatment containing only NaCl; however, the use of KCl should be carried out with caution due to the risk of hyperkalemia in patients with kidney disease.

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