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Effect of Partial Substitution of Sodium Chloride with Potassium Chloride on Quality Characteristics of Buffalo Calf Meat Rolls

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ABSTRACT

The study was carried out to develop low salt buffalo calf meat rolls partially substituting sodium chloride with potassium chloride (maintaining equivalent ionic strength) at the levels of 10% to 50%. Substitution up to 30% level did not result in any significant variations in sensory attributes but further increase in potassium chloride level caused significant decline in flavor, tenderness, juiciness, texture and overall acceptability. The replacement did not cause any significant difference in proximate composition, water holding capacity, emulsion stability of developed meat rolls. Increase in pH and decrease in cooking yield values was observed with enhancement in level of potassium chloride but significant effect was noticed only at 50% replacement. Texture profile and instrumental color of KCL treated rolls were comparable to control. Firmness and toughness declined with increasing incorporation of KCl but significant impact was noticed only at 50% level. The replacement up to 30 % was optimum to develop low salt buffalo calf meat rolls.

HIGHLIGHTS

- To develop low salt buffalo calf meat rolls partially substituting sodium chloride with potassium chloride.
- Texture profile and instrumental color of KCL treated rolls were comparable to control.

Keywords: Buffalo calf, low salt, meat rolls, sodium chloride, potassium chloride, sensory quality

India exported 1.23 million tonnes of buffalo meat, worth ₹ 25091 crores in financial year 2018-2019 (APEDA, 2019). Unlike cow, buffalo meat does not have any religious connotations and its slaughter and export is permitted under the Indian laws. It has roughly 2-3 folds cost advantage over mutton and chevon. Even farmers do not consider raising male buffalo calf to be financially rewarding, eventually the country experiences immense loss in respect of elevated mortality rate (80 % to 84.69 %) on account of poor care and managemental practices (Tiwari *et al*., 2007). In India, buffalo meat is predominantly obtained from slaughter of used up dairy buffaloes at the end of their fruitful life after complete exploitation. The meat so acquired from spent animals is dark, rough and tough in texture and exhibit inferior sensorial and processing attributes (Kandeepan *et al.*, 2009; Naveena *et al.*, 2011). However, these all adversities can be sorted out by utilizing meat of young male buffalo calf below 1.5 years of age. Meat of such calves have greater collagen solubility (Kandeepan *et al*., 2009) since the collagen cross links get stabilized and the collagen become much less soluble with advancement in age (Maltin *et al.,* 1998). Sodium chloride is the principal ingredient in processed meat due to its preservative properties, capacity to improve taste, flavor and functional attributes to solubilise myofibrillar proteins. Diets high in sodium content have been identified as one of the dietary risk factors for various diseases (Lim *et al*., 2012). The recommendation of World

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Health Organization (WHO, 2003) suggests that daily salt consumption should not exceed 2 g/day for general public. Presently, sodium ranks second after calories as the ingredient most looked for by about 65% of people who read nutritional label of the product before buying (Sloan, 2010).

Total dietary salt intake by Americans is 10 to 12 g per day (Anon, 1980) and about 33% of Americans has been diagnosed with high blood pressure, a condition associated with excessive dietary sodium intake (Sloan, 2010). Various researchers have recommended that the partial substitution of sodium chloride with potassium chloride is one of the finest alternatives to alleviate the sodium level in meat products (Lorenzo *et al*., 2015a; Lorenzo *et al.,* 2015b; Dos Santos *et al.,* 2014; Campagnol *et al.,* 2011). The use of potassium chloride provides an additional benefit as potassium being a counter ion to sodium and diminishes the injurious outcome of sodium on blood pressure and the comparable perceived saltiness can be attained with lower sodium level (Wettasinghe and Shahidi, 1997; Puolanne *et al*., 1988). So, keeping all these facts in view, an attempt was made to develop low salt buffalo calf meat rolls by partially replacing sodium chloride with potassium chloride.

MATERIALS AND METHODS

Procurement and processing of raw materials

Healthy male buffalo calves (10 months of age) reared under similar feeding and managemental conditions were procured from nearby market and slaughtered and dressed as per the standard procedure. The dressed carcasses were washed thoroughly and deboned manually after trimming of visible fat and connective tissue. Deboned meat was packed in colorless low density polyethylene (LDPE) bags at -18±2°C. The frozen chunks were drawn and thawed overnight at 4±2°C and used for development of meat rolls.

Sodium chloride, STPP, sodium nitrite, citric acid, sugar (used in powder form), groundnut oil, bread crumbs powder and eggs were purchased from the local market. Water was used in chilled form. Potassium chloride was procured from reputed firms for use as salt substitute. The condiment mix was prepared by mixing onion and garlic paste (ratio 2:1) and packed in LDPE bags and stored at -18±2 ºC till further use.

Preparation of buffalo calf meat rolls

For preparation of control meat rolls, sodium chloride (2%), sodium tripolyphosphate (0.5 %), sodium nitrite (150 ppm), spice mix (2 %), condiments paste (3 %), chilled water (10 %), groundnut oil (7 %), bread crumbs powder (4 %), whole egg liquid (8 %), sugar (1 %) and citric acid (0.05 %) were mixed with double minced meat. Stable emulsion was prepared in a meat chopper. The prepared emulsion was stuffed manually in autoclavable beakers and distributed uniformly. The beakers were covered with aluminium foil and steam cooked in a closed container for 35 minutes. After cooking, rolls were taken out and cooled to room temperature, packaged in polythene bags and stored at 4 ±2 °C for further evaluation.

For preparation of low salt meat rolls, sodium chloride was partially substituted with potassium chloride maintaining equivalent ionic strength (IS) to that of 2 % Sodium chloride (0.342). Substitution of 10 %, 20 %, 30 %, 40 % and 50 % of sodium chloride was done with salt substitute.

Analysis

Ionic Strength

Ionic strength was calculated as follows:

$$y = ½ \sum MZ^2$$

Where, y = ionic strength, M = molality, Z = charge on the ion

Sensory quality

An semi trained panel consisting faculty and research fellows evaluated the meat rolls for the sensory attributes of color and appearance, flavor, texture, tenderness, juiciness and overall acceptability using 8-point descriptive scale (Keeton, 1983), where 8 representing excellent and 1 indicating extremely poor. The warmed test samples were served to the panelists only after assigning the suitable codes. Water was provided for rinsing the mouth between different samples.

Physicochemical characteristics and proximate composition

The pH of meat emulsion and cooked meat rolls was determined following method of Trout *et al*. (1992). Emulsion stability of control as well as KCl incorporated t emulsions was measured using the method of Baliga and Madaiah (1970). WHC (water holding capacity) was determined as per procedure of Wardlaw *et al*. (1973) with slight modification. Cooking yield was estimated by considering the weight of the cooked meat rolls and initial raw weight and represented as a percentage. Proximate composition was determined by following the standard methods of AOAC (2005).

Texture profile analysis (TPA)

The textural properties (hardness, springiness, cohesiveness, gumminess and chewiness) of meat rolls were determined by Texture Analyser (TA.HD plus), Stable Micro Systems Ltd., Surrey, England with the Texture Exponent Program. A compression platform of 70 mm diameter was employed as a probe. The analysis of textured TPA was executed according to the method designed by Bourne (1978). Test samples (2 cm^3 size) were compressed to 50 % of their original height. A 5 seconds time was permitted between the two compression cycles. Force time deformation curves were obtained with a 50 kg load cell used at a cross-head speed of 2 mm/s.

Shear press value

The force required to shear a 1 cm^3 size sample of meat rolls transversely was determined using Warner-Bratzler shear probe of texture analyser and indicated as firmness (Kg/cm^3) and toughness (Kg-sec).

Instrumental color analysis

Instrumental color of meat rolls was evaluated using a Konica Minolta chroma meter CR-400 (Konica Minolta Sensing, Inc., Japan) with 8 mm aperture after calibrating with a white standard plate. Color was represented as CIE Lab, L* (lightness), a* (redness) and b* (yellowness).

RESULTS AND DISCUSSION

Sensory quality

No significant difference was noticed in color and appearance scores even up to 50 % substitution of sodium chloride with potassium chloride (by maintaining equivalent ionic strength) in comparison to control meat rolls containing 100 % sodium chloride (Table 1). The flavor scores of control and treated rolls substituting 10 %, 20 % and 30 % sodium chloride with potassium chloride were comparable and were more than 7.0 indicating more than very good desirability on 8 point descriptive scale. Further increase in potassium chloride level at 40 % and 50 % resulted in significant decrease in flavor scores. Meat rolls containing 50 % potassium chloride had flavor scores of 5.67 indicating less than moderate acceptability. Alves *et al*. (2017) also observed that replacement of 50% sodium chloride with potassium chloride resulted in slightly diminished salty taste and a little bitter, astringent and metallic flavor in reduced fat low salt bologna type sausages.

Table 1: Effect of partial replacement of sodium chloride with potassium chloride on sensory scores of buffalo calf meat rolls (Mean ± SD) (n=12)

Treatments	Color and Appearance	Flavor	Texture	Juiciness	Tenderness	OAA
Control NaCl (100 %)	$7.83^{a} \pm 0.33$	$7.83^{a} \pm 0.39$	$7.83^{a} \pm 0.33$	$7.88^{a} \pm 0.31$	$7.88^{a} \pm 0.31$	$7.83^{a} \pm 0.39$
NaCl + KCl (90 % + 10 %)	$7.83^{a} \pm 0.39$	$7.83^{a} \pm 0.33$	$7.75^{a} \pm 0.45$	$7.83^{a} \pm 0.39$	$7.79^{a} \pm 0.40$	$7.79^{a} \pm 0.40$
NaCl + KCl (80 % + 20 %)	$7.79^{a} \pm 0.40$	$7.71^{a} \pm 0.40$	$7.71^{a} \pm 0.45$	$7.75^{a} \pm 0.45$	$7.71^{a} \pm 0.45$	$7.71^{a} \pm 0.45$
NaCl + KCl (70 % + 30 %)	$7.75^{a} \pm 0.45$	$7.46^{a} \pm 0.50$	$7.50^{ab} \pm 0.52$	$7.46^{ab} \pm 0.45$	$7.58^{ab} \pm 0.51$	$7.54^{a} \pm 0.50$
NaCl + KCl (60 % + 40 %)	$7.75^{a} \pm 0.40$	$6.73^{b} \pm 0.45$	$7.08^{bc} \pm 0.36$	$7.13^{bc} \pm 0.31$	$7.17^{bc} \pm 0.39$	$6.88^{b} \pm 0.43$
NaCl + KCl (50 % + 50 %)	$7.71^{a} \pm 0.45$	$5.67^{c} \pm 0.49$	$6.88^{c} \pm 0.31$	$6.83^{c} \pm 0.39$	$6.96^{c} \pm 0.33$	$5.96^{c} \pm 0.33$

Means with different superscripts in a column differ significantly ($P \leq 0.05$).

The scores for texture, juiciness and tenderness were also comparable up to 30 % substitution. Further substitution of Sodium chloride with potassium chloride at 40 % and 50 % resulted in significant decline in texture, juiciness and tenderness scores. Bidlas and Lambert (2008) reported that partial replacement of sodium chloride with potassium chloride generally had adverse effect on flavor and texture of the meat products.

The overall acceptability score was highest for control which decreased with each substitution level but did not significantly declined up to 30 % replacement. Overall acceptability scores reduced significantly at 40 % and 50 % levels in comparison to control which might be due to decline in scores of flavor and other sensory attributes at these levels of replacement. The mean overall acceptability score was around 6.0 at 50 % level of replacement which indicates moderate acceptable on 8 point descriptive scale. Replacement of sodium chloride with potassium chloride beyond a certain limit results in sensory denial which is attributed to perception of bitter and metallic taste (Dos Santos *et al*., 2014; Lorenzo *et al*., 2015b).

Physico-chemical characteristics

No significant difference was noticed in the pH of raw emulsion among control, 10 %, 20 %, 30 % and 40 % replacement level but pH was significantly elevated when 50 % of sodium chloride was substituted with potassium chloride (Table 2). The results were in accordance with findings of Alves *et al*. (2017) who reported that substitution of sodium chloride with potassium chloride resulted in significantly higher pH as compared to the control. Horita *et al*. (2011) also noticed significantly higher pH readings in mortadella sausages with 50 % substitution of sodium chloride with potassium chloride. The pH values of cooked meat rolls also demonstrated similar trend. There was increase in pH after cooking which was because of increase in salt level owing to deprivation of moisture and alteration in net charge due to denaturation of proteins on cooking (Babu *et al*., 1994). Nath *et al*. (1996) noticed 0.3 to 0.4 units increase in pH after cooking.

No significant difference in WHC was observed between control and substituted samples although a decreasing trend with increased potassium chloride level was noticed. The results were in conformance with findings of Gimeno *et al*. (1998) who revealed that there was no significant change in WHC after substitution of sodium chloride with a mixture of sodium chloride, potassium chloride, $MgCl_2$ and $CaCl_2$ at equivalent ionic strength to that of control.

Emulsion stability also gradually decreased with increasing substitution level but no significant effect was noticed between control and treated rolls. Alves *et al*. (2017) also observed no significant differences in percent water and fat release among the treatments when sodium chloride was replaced by potassium chloride in low fat bologna type sausages.

Cooking yield also declined with enhancement in potassium chloride level in treated rolls and significant decrease in comparison to control was noticed at 50 % incorporation. This might be due to marginal decrease in water holding capacity and emulsion stability which resulted in significant decrease in cooking yield at highest level of substitution. Substitution of sodium chloride with potassium chloride at 50 % level did not result in significant differences in cooking loss in comparison to

Table 2: Effect of partial replacement of sodium chloride with potassium chloride on physico-chemical properties of emulsion and buffalo calf meat rolls (Mean ± SD) (n=6)

Treatments	pH (Raw emulsion)	pH (Cooked)	Water holding capacity (%)	Emulsion stability (%)	Cooking Yield (%)
Control NaCl (100 %)	$5.98^{b} \pm 0.05$	$6.11^{b} \pm 0.06$	$42.78^{a} \pm 2.33$	$79.90^{a} \pm 0.87$	$85.07^{a} \pm 1.34$
NaCl + KCl (90 %+10 %)	$5.99^{b} \pm 0.07$	$6.14^{ab} \pm 0.06$	$42.34^{a} \pm 2.34$	$79.75^{a} \pm 1.03$	$84.94^{a} \pm 1.37$
NaCl + KCl (80 %+20 %)	$6.01^{ab} \pm 0.06$	$6.15^{ab} \pm 0.07$	$41.78^{a} \pm 2.45$	$79.73^{a} \pm 1.06$	$84.76^{a} \pm 1.45$
NaCl+KCl (70 %+30 %)	$6.03^{ab} \pm 0.03$	$6.18^{ab} \pm 0.04$	$40.89^{a} \pm 2.62$	$79.58^{a} \pm 0.90$	$84.12^{ab} \pm 1.34$
NaCl+KCl (60 %+40 %)	$6.06^{ab} \pm 0.03$	$6.20^{ab} \pm 0.04$	$39.83^{a} \pm 2.63$	$79.10^{a} \pm 1.22$	$83.39^{ab} \pm 1.24$
NaCl+KCl (50 %+50 %)	$6.09^{a} \pm 0.04$	$6.23^{a} \pm 0.06$	$38.73^{a} \pm 2.54$	$78.42^{a} \pm 1.02$	$82.23^{b} \pm 1.42$

Means with different superscripts in a column differ significantly ($P \leq 0.05$).

control samples (Alves *et al*., 2017). Choi *et al*. (2014) also indicated no significant impact on cooking loss or moisture content of the low sodium frankfurter sausages when 40 % sodium chloride was replaced by potassium chloride or combination of potassium lactate and calcium ascorbate. Pietrasik and Gaudette (2015) concluded that ionic strength and not the type of ions play vital role in preserving protein extraction ability and moisture retention potential. Reduction of sodium chloride up to 25 % level did not affect the yield and purge loss of frankfurters during storage (Tobin *et al*., 2013).

Proximate composition

Replacement of sodium chloride with potassium chloride did not influence the moisture content of meat rolls significantly (Table 3). No significant difference was noticed in the protein content of control and salt substituted samples. Fat and ash content did not vary significantly among control and treatments and increasing level of potassium chloride did not cause any significant impact on fat and ash content of meat rolls. No significant change in proximate attributes might be due to similar composition of emulsion and no effect of substitution of sodium chloride with potassium chloride. The findings of proximate composition were in accordance with Alves *et al*. (2017) who depicted that replacement of sodium chloride with potassium chloride did not significantly alter moisture, protein, ether extract and ash content of low fat bologna type sausages. Horita *et al*. (2011) formulated low fat bologna sausages by partially replacing sodium chloride with other chloride salts and did not observe any difference in proximate composition.

Texture profile analysis

No significant difference in hardness was observed between control and treatments although a decreasing trend in hardness with increased KCl level was noticed (Table 4). Springiness is the ability of the sample to recover its original form after a deforming force is removed whereas cohesiveness is the extent to which sample

Table 3: Effect of partial replacement of sodium chloride with potassium chloride on proximate composition of buffalo calf meat rolls (Mean ± SD) (n=6)

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Control NaCl (100 %)	64.27^{a} ± 0.51	19.42^{a} ± 0.70	7.72^{a} ± 0.48	2.95^{a} ± 0.32
NaCl + KCl (90 %+10 %)	63.97^{a} ± 0.93	19.67^{a} ± 0.60	7.33^{a} ± 0.93	3.01^{a} ± 0.26
NaCl + KCl (80 %+20 %)	63.99^{a} ± 0.92	19.50^{a} ± 0.55	7.54^{a} ± 0.67	2.96^{a} ± 0.33
NaCl + KCl (70 %+30 %)	64.15^{a} ± 0.89	19.18^{a} ± 0.72	7.42^{a} ± 0.74	2.90^{a} ± 0.23
NaCl + KCl (60 %+40 %)	63.70^{a} ± 0.82	19.45^{a} ± 0.81	7.52^{a} ± 0.80	2.99^{a} ± 0.26
NaCl + KCl (50 %+50 %)	63.83 ± 1.05	19.46^{a} ± 0.57	7.54^{a} ± 0.74	2.93^{a} ± 0.35

Means with different superscripts in a column differ significantly ($P \leq 0.05$).

Table 4: Effect of partial replacement of sodium chloride with potassium chloride on texture profile of buffalo calf meat rolls (Mean ± SD) (n=6)

Treatments	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)
Control NaCl (100 %)	43.63^{a} ± 4.46	0.85^{a} ± 0.02	0.62^{a} ± 0.08	26.59^{a} ± 2.16	22.56^{a} ± 1.97
NaCl + KCl (90 %+10 %)	43.42^{a} ± 3.75	0.84^{a} ± 0.04	0.61^{a} ± 0.04	26.65^{a} ± 3.89	22.27^{a} ± 3.25
NaCl + KCl (80 %+20 %)	42.38^{a} ± 3.09	0.85^{a} ± 0.04	0.66^{a} ± 0.06	27.98^{a} ± 3.92	23.90^{a} ± 4.35
NaCl + KCl (70 %+30 %)	41.15^{a} ± 3.46	0.86^{a} ± 0.03	0.69^{a} ± 0.05	28.33^{a} ± 3.20	24.51^{a} ± 3.41
NaCl + KCl (60 %+40 %)	39.85^{a} ± 3.27	0.82^{a} ± 0.05	0.61^{a} ± 0.07	24.04^{a} ± 2.23	19.77^{a} ± 2.28
NaCl + KCl (50 %+ 50%)	37.83^{a} ± 2.81	0.84^{a} ± 0.03	0.67^{a} ± 0.06	25.38^{a} ± 1.58	21.43^{a} ± 1.90

Means with different superscripts in a column differ significantly ($P \leq 0.05$); N- Newton.

can be deformed prior to rupture. Both springiness and cohesiveness were comparable for control and KCl treated meat rolls. The gumminess and chewiness values were also comparable for control and KCl treated meat rolls. Results of instrumental texture profile showed that replacement of NaCl with KCl (maintaining equivalent ionic strength) did not have any significant negative influence on the textural attributes of the cooked meat rolls. These findings were in agreement with those reported by Alves *et al*. (2017) who observed that 50 % substitution of NaCl with KCl did not alter significantly the readings of hardness, springiness, cohesiveness, gumminess and chewiness of bologna type sausages with respect to control.

Similarly, Horita *et al*. (2011) noticed no significant difference in hardness values of emulsified mortadella when 50 % of NaCl was substituted with KCl. Choi *et al*. (2014) reported that frankfurter sausages containing NaCl upto 60 % of control had similar hardness, springiness, cohesiveness and chewiness values as control sample. The springiness of bologna type sausages did not show significant changes between the control and salt substituted sample (Yang *et al*., 2007). The texture of the product relies on the structure and integrity of the protein matrix developed during cooking and lowering or substituting NaCl content with other salt in the sausages resulted in softer texture as compared to control (Pietrasik and Gaudette, 2015).

Firmness and toughness

Replacement of NaCl with KCl up to 40% level did not result in any significant effect on firmness and toughness of meat rolls although a decreasing trend for firmness and toughness was noticed (Table 5). Further replacement of NaCl with KCl to 50% level resulted in significant decrease in firmness and toughness values of meat rolls. Hand *et al*. (1982) reported that substitution of NaCl with 100 % KCl or $MgCl_2$ significantly decreased the firmness of turkey frankfurters but 35 % substitution did not affect firmness significantly.

Table 5: Effect of partial replacement of sodium chloride with potassium chloride on firmness (Kg/cm^3) and toughness (Kg-sec) of buffalo calf meat rolls (Mean ± SD) (n = 6)

Treatments	Firmness (Kg/cm^3)	Toughness (Kg-sec)
Control NaCl (100 %)	0.94^a ± 0.03	10.42^a ± 0.33
NaCl+KCl (90 %+10 %)	0.94^a ± 0.06	10.39^a ± 0.36
NaCl+KCl (80 %+20 %)	0.93^{ab} ± 0.11	10.21^{ab} ± 0.20
NaCl+KCl (70 %+30 %)	0.91^{ab} ± 0.07	10.11^{ab} ± 0.15
NaCl+KCl (60 %+40 %)	0.89^{ab} ± 0.05	9.98^{ab} ± 0.22
NaCl+KCl (50 %+50 %)	0.82^b ± 0.11	9.87^b ± 0.36

Means with different superscripts in a column differ significantly ($P \leq 0.05$).

Table 6: Effect of partial replacement of sodium chloride with potassium chloride on instrumental color values of buffalo calf meat rolls (Mean ± SD) (n = 12)

Treatment	L* (lightness)	a* (redness)	b* (yellowness)
Control NaCl (100 %)	62.40^a ± 0.88	9.14^a ± 0.39	16.54^a ± 0.48
NaCl + KCl (90 %+10 %)	62.03^a ± 0.84	9.36^a ± 0.43	16.20^a ± 0.45
NaCl + KCl (80 %+20 %)	62.19^a ± 0.77	9.25^a ± 0.48	16.27^a ± 0.47
NaCl + KCl (70 %+30 %)	61.74^a ± 0.94	9.43^a ± 0.44	16.44^a ± 0.50
NaCl + KCl (60 %+40 %)	61.68^a ± 0.86	9.50^a ± 0.49	16.49^a ± 0.42
NaCl + KCl (50 %+50 %)	62.27^a ± 0.75	9.28^a ± 0.42	16.35^a ± 0.39

Means with different superscripts in a column differ significantly ($P \leq 0.05$).

Instrumental Color

The L* (lightness) values did not change significantly with substitution of NaCl with KCl. Similarly no significant effect was observed on a* (redness) and b* (yellowness) values. The results revealed that substitution of NaCl with either KCl did not impart any negative influence on instrumental color values of buffalo calf meat rolls.

The results were in conformance with the findings of Horita *et al*. (2011) who observed no significant difference in instrumental color values of emulsified mortadella sausages when 50 % of NaCl was substituted with KCl. The 50 % substitution of NaCl with KCl did not alter significantly readings of L*, a* and b* of bologna type sausages (Alves *et al*., 2017).

CONCLUSION

The study revealed that replacement of sodium chloride up to 30 % did not result in any significant variation in sensory quality but further increase in potassium chloride level caused significant decline in sensory quality buffalo calf meat rolls. Partial substitution did not result in any significant variation in proximate composition, water holding capacity and emulsion stability, instrumental texture profile and color. Increase in pH and decrease in cooking yield, firmness and toughness values was observed with enhancement in level of potassium chloride but significant effect was noticed only at 50 % replacement. It was concluded that buffalo calf meat rolls replacing 30 % sodium chloride with potassium chloride (maintaining equivalent ionic strength) were comparable with control in terms of sensory quality, physico-chemical properties, proximate composition and instrumental attributes.

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