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Effect of sodium bicarbonate residue on some characteristics of processed meat products

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Abstract: Using sodium bicarbonate (SB) in cooking meat products is a controversial subject. The aim of this study was to estimate an effect of different SB concentrations on the quality characteristics and organoleptic properties of meat in Kubideh Kebab, an Iranian popular meat product. Ground meat was divided into four groups (a, b, c, and d). After that, SB was added in ratio 0.25, 0.50, 1.00, and 2.00 g/kg respectively. A sample without SB was considered as a blank sample. The Kebab samples were prepared and cooked properly at 350°C for 4–6 minutes and at 450°C for 2–4 minutes. A significant difference was observed in the pH values and the cooking loss between the blank sample and those Kebab samples that were cooked at 350°C and 450°C and pre-treated with SB in the amount of 0.25–2.00 g per 1 kg of meat ($P < 0.05$). The amount of residual bicarbonate ions increased significantly in the cooked Kebab samples at both treatment temperatures in the a-d group in comparison with the blank sample, as well as between the groups ($P = 0.00$). The organoleptic properties did not change in the a-d groups in comparison with the blank sample.

Keywords: Ion chromatography, Kebab, meat, sodium bicarbonate

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INTRODUCTION

Kebab is a traditional and highly consumed food which is extremely popular in Iran, Anatolia, Central Asia, Russia, and Armenia. It is made from ground lamb, beef, or poultry mixed with chopped onion. To cook Kubideh kebab, one originally had to place meat on a flat stone and smash it with a mallet; modern Kubideh kebabs are made from ground meat barbecued with herbs, tomato and green pepper. Marinating is a traditional technique used to improve the meat quality before thermal treatment. Beef is soaked in marinade (water, salt, and other essential ingredients); alternatively, the marinade can be injected into the meat. Marinating improves meat flavour and prolongs shelf life, since spices and various extracts provide it with antimicrobial and antioxidant properties [1]. Some researches show that nonmeat additives increase the water holding capacity (WHC) of the processed meat [2]. Being a base component of raw meat, water is not a valuable additive for meat products. However, it is usually considered as a nonmeat additive [3]. In general, pH in the isoelectric point of myofibrillar proteins (5.2–5.3) corresponds to the lowest level of water holding capacity. Thus, it is possible to increase the WHC of meat products by accreting the ionic backbone as a result of pH adjustment [4–6].

According to Offer and Trinick [7], it is possible to improve WHC using marinating, since electrostatic repulsion makes beef fibres expand, which allows the added water to penetrate into the myofibrillar network. It is known that some additives are able to enhance the low moisture assimilation of meat products, and sodium chloride and phosphates are among them [1]. Actually, the application of sodium chloride concentrations alignment from 4.6 to 5.8% provides the optimal amplification of myofibrils distension with the optimal damp uptake. It has been universally accepted that sodium chloride alters the solubilization of myofibrillar protein, water absorption, and gelling properties of meat [4–6]. This mechanism of improving the WHC of meat by using sodium chloride was recommended by Offer and Knight [8] and Ruusunen and Puolanne [9]. Moreover, the application of phosphate salts also improves the water retaining and the binding capacities of meat [10]. For instance, by adding 0.3% of phosphate in beef, one can raise its pH, promote the formation of ionic bonds, as well as magnesium- and calcium-binding proteins with an increase in the solubilization of myosin and actin.

In addition, Xiong et al [11] observed a strong synaeresis between sodium chloride and phosphate in poultry meat. Hence, marinades with sodium chloride and polyphosphates are used to improve various characteristics of muscle-based meat [12, 13–14]. Although it is universally accepted that phosphates affect meat characteristics, some countries banned their use in meat processing [3]. Therefore, phosphates can be replaced some of alternative substances in meat products. Only a few studies focused on the use of bicarbonate to improve the quality of pork [15, 16–17] and poultry [18, 19]. Furthermore, some recent empiric studies actually promote the efficiency of SB ($NaHCO_3$) in pork and poultry products because it can reduce shear force [20–22]. Bicarbonates possess a higher buffering capacity and ionic potency, if compared with phosphates, which explains their efficiency [17]. Unlike sodium chloride and polyphosphates, the basic mechanisms of the SB action remain understudied. The researches mentioned above studied meat marinated with sodium chloride, polyphosphate, and bicarbonate. However, there is a significant gap in data concerning the role of water with the biopolymers injected inside the intra- and extramyofibrillar spaces during marinating.

On the other hand, marinating increases the product yield, reduces the water loss during cooking [23], and raises the tenderness of meat. As a rule, the main ingredients of marinade are sodium chloride and phosphates [23]. Both can improve WHC by increasing the electrostatic repulsion of myofibrillar proteins [23]. Another effective ingredient is SB, as it reduces drip loss and shear force [17, 24–25] and increases the yield of cooked meat [24, 26]. By marinating sirloin and flank in a SB solution, one can achieve a balance between flavour, tenderness, and cost. Generally, the WHC of meat is minimal when its pH is close to the isoelectric point of myofibrillar proteins (about 5.2–5.5). The ionic strength could be steadily increased by adjusting the pH, thus leading to a higher level of WHC in meat products [27]. It is believed that the organoleptic properties of cooked meat, such as flavour, smell, appearance, and palatability, depend not only upon the pH of the muscle tissue and its nutritional status at the time of slaughter but also upon the type of ingredients used in marinating. The cooking loss tended to decrease as SB level went higher: the cooking loss reduced by 1.8% when the concentration of SB was 0.10% per unit. The use of SB did not change the overall appearance of meat, while reducing its hardness [28]. Additionally, SB is an excellent marinating agent: it can be used to process poultry with no phosphates added, which meets the demand and raises the nutritional properties. A recent research showed that the highest marinade performances were achieved when SB was combined with phosphates [24]. The present research focused on evaluating the effect of different concentrations of SB on the quality characteristics and the organoleptic properties of kebab meat cooked at different temperatures.

Table 1. Properties of the lamb meat used for preparing kebab samples

Parameter	Results
Total bacteria, per g	4.2×10^5
Moisture, %	65.4
Protein, %	16.84
Total fat, %	16.6
Total starch, %	trace
Ash, %	1.39

Table 2. Properties of the kebab samples cooked at 350°C and 450°C

Parameter	Results at 350°C	Results at 450°C
Total bacteria, per g	1.1×10^5	10^5
Moisture, %	55.5	55.1
Protein, %	16.52	16.30
Total fat, %	16.40	16.22
Total starch, %	trace	trace
Ash, %	2.3	2.3

STUDY OBJECTS AND METHODS

Chemicals and reagents. Sodium bicarbonate, sodium chloride, nitric acid, and sodium hydroxide were supplied by Merck (Darmstadt, Germany). Distilled and deionized water with 18.0 MΩ specific resistance was prepared by Milli Q Water System (Millipore, Le montsur-Lausanne, Switzerland).

Sampling. To prepare kebab samples, sirloin and mutton flank (13:1, w/w) were pounded and mixed with salt, a diluted saffron solution, grated onion, and black pepper. This mixture was divided into four groups: a, b, c and d. The groups contained 0.25, 0.50, 1.00, and 2.00 g/kg of SB respectively; an individual blank group was provided for the raw and the cooked samples. For each group, five kebab samples were prepared and cooked at two different temperatures: 1) 350–400°C with a long cooking period (4–6 min), the internal temperature of meat being 68–70°C); 2) 450–500°C with a short cooking period at (2–4 min), the internal temperature of meat being 89–91°C.

Sample preparation. Initially, 1.50 g of each raw and cooked Kebab sample were mixed with 10 ml of concentrated nitric acid (65%) and homogenized with a magnetic stirrer for at least 3.0 hours until a completely transparent liquid was obtained. Then the samples were diluted with NaOH 1.0 M and put in an 80 ml (volumetric flask. Finally, the pH of the extracts was adjusted to 8.3–8.7 by NaOH 10 M, and the extract solutions were filtered by a 0.45 µm filter before being injected into the ion chromatograph. These experiments were conducted in three replicates for each sample.

Equipment. A Metrohm 844 UV/Vis compact ion chromatograph was used to identify and determine bicarbonate ions in the extracted samples. A Rehodyne model 7725i injector with a 50 µL loop was used to inject the extracted samples. Chromatographic separations were achieved using an anionic A Supp 8, 5 µm, 4.0 × 150 mm analytical column. A degassed and filtered solution of sodium chloride was used as a mobile phase. Due to this, 10.0 g of sodium chloride was dissolved in some deionized water in a 100 mL volumetric flask and then diluted up to its volume. This solution was conveyed in the isocratic mode at a flow rate of 1.0 mL/min. All the analyses were carried out at 215 nm, and the ion chromatographic data were acquired and processed using PC and IC Net Ver. 1.1 chromatography manager software.

Determination of pH in the kebab samples. The pH value of meat samples was determined according to the standard method of ISO 2917:1999 [29]. A calibrated digital Metrohm pH meter (model 744) equipped with a combined glass–calomel electrode was used to obtain the pH of meat samples and control the pH of the solutions, as well as to adjust the mobile phase in the chromatographic analysis.

Estimation of organoleptic properties. The hedonic test method was used to estimate the organoleptic properties (smell, flavor, appearance, and palatability) of the kebab samples. The samples were labeled with a random three-digit number and then served to forty panellists. This protocol was used to estimate the smell, appearance, flavour, and palatability of Kubideh kebab using a 9-point hedonic scale.

Cooking loss. The raw meat samples were slightly blotted with paper towels and weighed, then cooked separately at two temperature levels: 350–400°C for 4–6 minutes and 450–500°C for 2–4 minutes. After that, the cooked samples were once again slightly blotted with paper towels and weighed. The cooking loss was calculated as follows:

$$\%\ \text{Cooking loss} = \frac{W1-W2}{W1} \times 100,$$

where w_1 = Weight of raw meat before cooking, and w_2 = Weight of meat after cooking

Chemical and microbial properties of the lamb. A few physicochemical and microbial properties of the lamb used for preparing kebab samples were determined for each sample. The moisture was determined by calculating the meat weight after drying it at 105 ± 2°C. The meat protein content was determined by the Kjeldahl method. The meat fat was analyzed using the Soxhlet apparatus method. The carbohydrates were measured by the starch test. The ash content was determined using a 600°C furnace [30]. Likewise, all the meat samples were analyzed for the total of aerobic mesophilic microorganisms using the aerobic plate count (APC) of colony forming units (CFU) and reported as log CFU per g of meat samples using the Ercolini et al. [31].

Statistical analysis. All the data were analyzed using SPSS software. The significant differences between the treatments were assigned by using the paired samples t-test at a 5% probability level ($P < 0.05$). It was carried out to reveal the difference between two individual parameters. It was performed using statistical SPSS version 16 software.

RESULTS AND DISCUSSION

Chemical and microbial properties of the lamb. Tables 1 and 2 show the main chemical and microbial properties of the lamb. In this study, the total content of the bacteria was studied to ensure that the meat was safe for human consumption and to determine how the pH value was affected by bacteria activity. The total of bacteria, % moisture, % protein, % total fat, % total starch, and % ash contents were compatible with the national regulations of Iran for meat products.

Physicochemical properties of the marinated raw and cooked samples. All of the treated samples were estimated for pH, cooking loss, and the amount of bicarbonate ions before and after cooking. Tables 3, 4, and 5 show the effects of marinating ingredients and heat treatment. The results revealed that the a-d marinated meat samples had a higher pH value, more bicarbonate ions, and a lower cooking loss compared to the control groups ($P < 0.05$). Petracci et al [29] showed that breast fillets treated with SB and cooked at the maximum heat (80–200°C) had a higher ability to retain water than those treated with phosphate (67.3 vs. 65.7%, $P < 0.05$). Marinating ingredients including sodium chloride accounted for an increase in the solubility of meat proteins as well as an increase in the ionic strength [23]. SB and sodium tripolyphosphate (STPP) increased the number of the ions that reacted with the protein and increased hydration [17, 32].

In addition, a combination of two or more of these ingredients has been reported to result in a lower cooking loss than when they are used individually [26]. It was found that the drip loss correlated with protein solubility increasing the solubility of myofibrillar, sarcoplasmic, and total proteins [28]. In addition, SB produced holes during cooking due to the generation of carbon dioxide leading to a coarser microstructure which could also improve the physical entrapment of water [26].

There was no significant dependence between the SB content and the cooking temperature. The statistical analysis revealed that there was no significant correlation between an increase in the amount of SB from 0.25 to 2.00 g/kg in the meat samples (a-d groups) and the cooking temperature from 350°C to 450°C. The similar was observed for the pH value and the cooking loss. However, the amount of bicarbonate ions decreased when the temperature changed from 350°C to 450°C (Fig. 1).

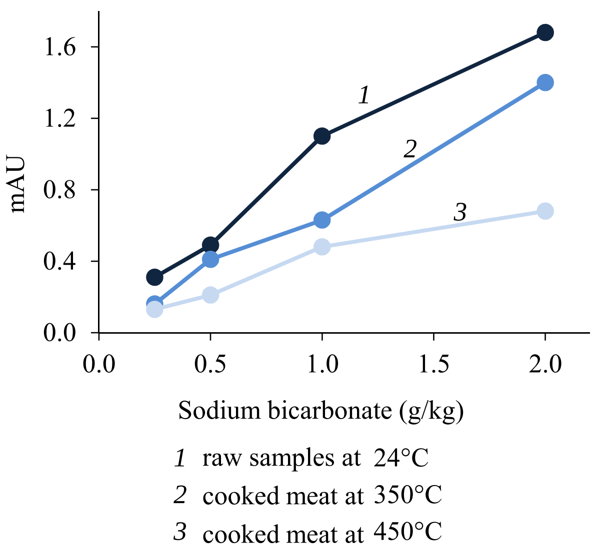


Fig. 1. Mean amount of sodium bicarbonate (as mAU) in the raw and cooked samples at 350°C and 450°C.

Table 3. Physicochemical properties of the marinated raw samples compared to the control sample

pH	Raw samples							
	a		b		c		d	
	mean	*P*	mean	*P*	mean	*P*	mean	*P*
	6.10 ± 0.00	0.03	6.20 ± 0.00	0.01	6.30 ± 0.00	0.01	6.56 ± 0.05	0.01
Bicarbonate ions, mg/g	0.31 ± 0.00	0.00	0.49 ± 0.00	0.00	1.10 ± 0.01	0.00	1.68 ± 0.00	0.00

Note. a: 0.25 g of sodium bicarbonate per kg meat, b: 0.50 g of sodium bicarbonate per kg meat, c: 1.00 g of sodium bicarbonate per kg meat, d: 2.00 g of sodium bicarbonate per kg meat
The data were represented as the mean ± standard deviation of triplicate tests. The differences between the analyzed physicochemical properties of marinated raw samples compared to the control were statistically significant (P < 0.05).

Table 4. Physicochemical properties of the marinated cooked samples at 350°C compared to the control sample

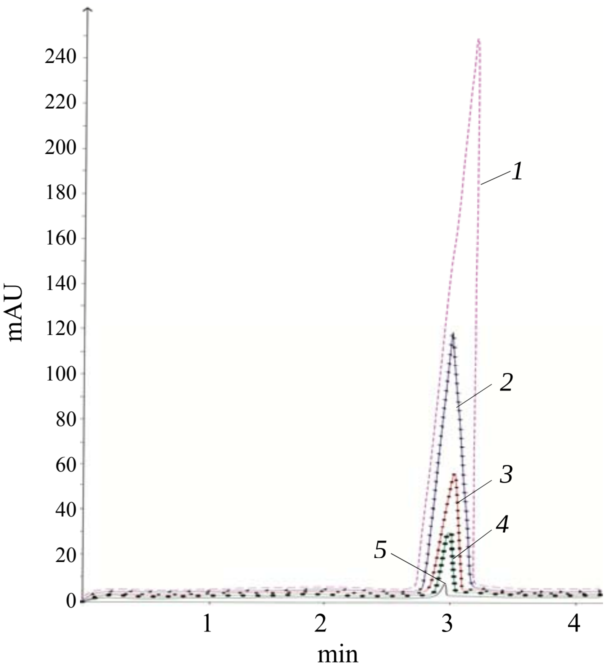
pH	Cooked samples at 350°C							
	a		b		c		d	
	mean	*P*	mean	*P*	mean	*P*	mean	*P*
	6.16±0.05	0.01	6.20±0.00	0.01	6.31±0.00	0.00	6.53±0.05	0.00
Cooking loss, %	25.0±0.03	0.03	24.0±0.02	0.00	23.0±0.01	0.00	21.0±0.00	0.00
Bicarbonate ions, mg/g	0.16±0.00	0.00	0.41±0.00	0.00	0.63±0.00	0.00	1.40±0.05	0.00

Note. a: 0.25 g of sodium bicarbonate per kg meat, b: 0.50 g of sodium bicarbonate per kg meat, c: 1.00 g of sodium bicarbonate per kg meat, d: 2.00 g of sodium bicarbonate per kg meat

Table 5. Physicochemical properties of the marinated cooked samples at 450°C compared to the control sample

pH	Cooked samples at 450°C							
	a		b		c		d	
	mean	*P*	mean	*P*	mean	*P*	mean	*P*
	6.14 ± 0.03	0.00	6.20 ± 0.00	0.01	6.32 ± 0.01	0.00	6.61 ± 0.01	0.00
Cooking loss, %	27.0 ± 0.00	0.04	27.5 ± 0.04	0.05	25.4 ± 0.04	0.05	21.0 ± 0.02	0.01
Bicarbonate ions, mg/g	0.13 ± 0.00	0.00	0.21 ± 0.00	0.00	0.48 ± 0.00	0.00	0.68 ± 0.00	0.00

Note. a: 0.25 g of sodium bicarbonate per kg meat, b: 0.50g of sodium bicarbonate per kg meat, c: 1.00g of sodium bicarbonate per kg meat, d: 2.00g of sodium bicarbonate per kg meat
The data were represented as the mean ± standard deviation of triplicate tests. The differences between the analyzed physicochemical properties of marinated cooked samples at 450°C compared to the control were statistically significant (P < 0.05).



1 – 2.00 gr/kg, *2* –1.00 gr/kg, *3* –0.50 gr/kg, *4* – 0.25gr/kg, *5* – blank

Fig. 2. Ion chromatograms of bicarbonate extracted from the a-d meat samples.

The amount of residual bicarbonate ions increased in cooked kebab samples at two different temperatures when the SB concentration was increased from 0.25 to 2.00 g/kg in meat, if compared to its value in the blank sample, as well as between the groups (*P* = 0.00). In this method, the amount of bicarbonate ions was decreased by increasing temperature from 350°C to 450°C in both the blank and the kebab samples (*P* = 0.00) (Fig 2). While $NaHCO_3$ was heated above 110°C, it was observed that both H_2O and CO_2 underwent some chemical changes. Hence, by increasing the core temperature of the cooked samples from 68–70°C (direct heating at 350°C) to 89–91°C (direct heating at 450°C), the level of bicarbonate ions decreased. The pH of the meat samples treated with bicarbonate did not change after cooking. This result was not in agreement with Sindelar et al, who found that the pH of marinated sow loins with bicarbonate and polyphosphate increased after cooking [33]. These outcomes were most likely because of the essential R groups of the amino acids (histidine) during heating. The second probable reason may refer to the nature of marinade environment, as the alkaline environment may increase the pH value after marinating.

Organoleptic evaluation. The sensory properties of Kubideh kebab were evaluated by 40 panellists according to a 9-point hedonic scale. The organoleptic properties (smell, appearance, flavour, and palatability properties) did not change when SB was added from 0.25 to 2.00 g/kg of meat, in comparison with the blank group. This differed from the results of a research that showed that Golek chicken marinated with NaCl/STPP/$NaHCO_3$ (Tr6) had the lowest acceptance score compared to other treatments ($P < 0.05$) because of the slight darkening of the meat surface. The darker colour of the meat was probably due to the denaturation of muscle protein after it reacted with $NaHCO_3$. The denaturation resulted in an increase in the reflection and scattering of light and, hence, a paler meat colour [23, 34], as well as in an increase in extracellular water as a result of the marinating process. However, Young & Lyon found no effect of salt and phosphate marinade on meat lightness [14].

CONCLUSION

Marinating lamb meat before processing it into Kubideh kebab affected the quality and the cooking loss of the product. It is the first time that the detection and determination of the residual of bicarbonate ions has been studied in cooked and raw meat. Kubideh kebab cooked at four different SB levels (from 0.25 to 2.00 g/kg) resulted in a high pH value, a high level of biacrbonate ions, and a low cooking loss at different temperatures, while no differences in its organoleptic properties were detected.

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