SODIUM IN PROCESSED MEATS PRODUCED BY LOCAL BUTCHERIES IN TSHWANE, SOUTH AFRICA

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ABSTRACT

The common use of sodium in different compositions, is as a preservative, for colouring, curing, flavouring and as a binding agent in processed meats, it is also used for improved shelf life and distinct palatability. Even with modern food processing methods, sodium is still essential in manufacturing of meat derivatives. Continuous consumption of high sodium diets is associated with adverse chronic health effects, such as cardiovascular diseases, hypertension, stroke, cancers, among others, which have been on the rise. As a result, there has been a global drive by organisations such as the World Health Organization (WHO) to advise member states to reduce dietary sodium levels in various foods, including processed meats. Consequently, South Africa promulgated the first sodium reduction regulations in Africa by 2013, intended to reduce sodium in certain foodstuffs, including processed meat products. The objectives of this study were to determine (1) the level of sodium in processed meats produced by local butcheries in the City of Tshwane (CoT), Gauteng, South Africa and (2) to compare the amount of sodium in processed meats, determined using the two South African legislated methods, namely Flame Atomic Absorption Spectroscopy (FAAS) and Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). A cross-sectional approach with qualitative and experimental dimensions approach was followed. Processed meat production records obtained from randomly selected butcheries in CoT (122) revealed that the top six commonly produced processed meats were boerewors (90.2 %), braaiwors (87.7 %), biltong (86.9 %), drywors (62.3 %), viennas (45.9 %) and burger patties (43.5 %). Subsequently, sampling (n=396) of the top six products from 66 randomly selected butcheries was done. The findings of the study revealed that processed meats analysed using ICP-AES and FAAS contained mean sodium levels of 1449 mg/100 g and 649 mg/100 g, respectively (p<0.0001), which were higher than the South African legal sodium limits. The concentration of sodium of products determined using ICP-AES (64.7 - 9201 mg/100 g) was significantly (p<0.0001) higher than in the same products analysed using FAAS (35.4 - 2351 mg/100 g). From the findings of this study, sodium reduction requires a concerted effort in enforcing the South African mandatory sodium limits in local butcheries in processed meats. The results of legislated sodium test methods must be comparable to ensure equal level of compliance.

**Key words:** meat products, sodium reduction, processed food, processed meat, sodium limits
INTRODUCTION

Sodium (Na) is used as a food preservative and has changed the nature of food processing due to its influence on palatability of food [1]. Different households and industrial products contain Na⁺ in different compositions, such as table salt, soda ash, baking soda, caustic soda, sodium nitrate, sodium nitrite, di- and tri-sodium phosphates, sodium thiosulphate and borax [2].

As in other parts of the world, urbanised South African consumers are influenced by westernised diets, which results in a high intake of energy-dense foods, such as processed meats, refined grains, added sugar and saturated fats [3,4]. Globally, the perception is that the consumption of processed meats is the second major contributor to increased dietary sodium intake after cereal products [5,6]. The most common source of sodium in processed foods is sodium chloride (table salt) [7]. The average sodium intake in South Africa is approximately 9-12 g/day/person [8], while Asian countries averaged 12 g/day/person [9]. An average of 30% of South Africans have a mean sodium consumption of 6-11 g/day/person [10]. There is an association between excess consumption of sodium and negative health effects [4,11] which include cardiovascular diseases such as hypertension and increased risk of stroke [12], gastric cancer [13], various other human cancers [14] and the occurrence of kidney stones, kidney disease and kidney failure [15]. Most of these diseases are the leading causes of death and disability in the modern era [16].

Combatting lifestyle diseases by reduction of dietary sodium intake has been a longstanding strategy. As a result CODEX established supplementary guidelines for sodium, which was adopted together with the WHO’s and the Heart and Stroke Foundation of South Africa’s recommendations of daily sodium consumption reduction to less than 5 g/day/person [17]. In order to cut down the consumption of sodium in the population’s daily diets to this concentration, it is necessary to consider formulation specifications by manufacturers, strict regulations and monitoring strategies by health authorities and consumer awareness [18]. By 2013, South Africa was the first country in Africa [19] to promulgate legal sodium limits in certain foods, including processed meat products [20]. Among other non-meat products, processed meats (cured and uncured) and raw processed meat sausages (all types) were specifically categorised as food categories seven, eight and nine, respectively, with maximum total sodium limits (TSL) [21]. Table 1 summarises the categories of processed meats and South Africa’s mandatory limits. Although the International Organisation for Standardization (ISO) has developed several procedures, South Africa has two legally prescribed methods, namely FAAS and ICP-AES [19]. As in other parts of South Africa, local butcheries
of the CoT are increasingly involved with the production of various types of processed meat. For the purpose of this study, a local butchery is defined as premises located in shopping malls and residential suburbs, not supermarket butcheries. The objectives of the study were: (1) to determine the level of compliance to legal TSLs by local butcheries that produce processed meat in the CoT, and (2) to compare the South African legally prescribed sodium testing methods.

MATERIALS AND METHODS

Study area
The CoT is a metropolitan municipality in the north of Gauteng Province, South Africa (latitudes 25°6'34.60" S to 26°4'41.12" S and longitudes 27°53'24.26" E to 29°5'54.31" E). Figure 1 shows a map of the location of the CoT and its seven respective regions.

Figure 1: Map of the location of CoT in South Africa [22]

A two-pronged cross-sectional approach with qualitative and experimental dimensions was followed for this study [10].

Processed meat products produced in local butcheries
A survey of local butcheries across the seven regions was conducted to determine the processed meat types and the volumes produced by each butchery. The number of butcheries in the respective regions came from an electronic database of the CoT. Table 2 shows the number of butcheries proportionately selected per
region, as determined by a statistician. Assessment of the 122 butcheries’ production records was with regard to the processed meats produced (as listed in SANS 885:2011) [23]. In addition, scrutinising the labels of prepacked spices used in the manufacturing of processed meat determined the different types of sodium-based ingredients.

Sampling of processed meats from the butcheries
To determine the TSLs, the six most produced processed meat products were sampled (N=396) from 66/122 (54.1 %) local butcheries (Region one = nine, Region two = nine, Region three = 14, Region four = 13, Region five = three, Region six = 15 and Region seven = three).

Collection of samples of top six produced processed meats
Approximately 150 to 200 g of each of the products were purchased, placed in clean zip-lock plastic bags, labelled with the product name, date of sampling and region, and sent (<10 °C) to the laboratory where it was frozen (-18 °C) until analysis.

Calibration of analytical instruments and validation of FAAS and ICP-AES
To calibrate the FAAS and the ICP-AES, a series of Na standards (0 to 5 mg/L for FAAS and 0 to 500 mg/L) were prepared from a stock solution. A canned meat (T01120QC; FAPAS QC Fera Science Ltd, Sand Hutton, York, UK, valid until 2028) Certified Reference Material (CMR) was used to validate the FAAS and ICP-AES methods. Linear regression was used to determine the relationship between the instrument response and the known concentration of the standards, as indicated in Figure 2. Both regression curves were linear (R² = 0.9969 for FAAS and R² = 0.9981 for ICP-AES) and the differences between the measured and predicted values were nearly 100 % fit to the regression model. There were no outliers, and the prediction of the dependent variable could be with limited error from the independent variable.
The canned meat CRM was used to validate the FAAS and ICP-AES. The mean sodium concentration acquired was 547 ± 15.3 mg/100 g obtained by FAAS and 582 ± 12.3 mg/100 g obtained by ICP-AES, results were within the certified sodium levels (548 – 653 mg/100 g) of the CRM.

Sample preparation and analysis

Defrosting of the processed meat samples took place in a defrosting booth at ambient temperature. The samples and certified reference material (CRM) were prepared and acid digested using the official AOAC Method 2011.14 [24]. A Shimadzu FAAS model A-6701F (Shimadzu, Kyoto, Japan). For ICP-AES, a Spectro ARCOS® ICP-AES (METEK, New Jersey, USA) was used.

Statistical analysis

Analysis of variance (ANOVA), using the software XLSTAT 2015.04.36025, determined any significant differences in the sodium concentrations and in butcheries. For evaluation of differences in proportions Chi-square ($\chi^2$) test was used. Where probability values of $p<0.05$ (CL 95 %) were considered as significantly different. The results were presented in graphs and tables.

RESULTS AND DISCUSSION

In total, there were 122 butcheries, proportionally across the seven regions of the CoT, interviewed and 396 processed meat samples were taken from the top six products sampled from 66 (54 %) butcheries and analysed for sodium levels. Table 3 provides proportional butchery distribution across the seven regions of the CoT and the distribution of the samples across the regions.
Providing for the size of butcheries (N=122), a distinction can be made between the following categories, based on the number of pay points per butchery: one pay-point (39.3 %), two to five pay points (50.0 %), and > five pay points (10.7 %). Figure 3 indicates the data analysis and top six processed meats amongst other products.

Processed meat production by butcheries in CoT
The top six processed meats produced by butcheries were boerewors (90.2 % of the butcheries), braaiwors (87.7 % of the butcheries), biltong (86.9 % of the butcheries), drywors (62.3 % of the butcheries), viennas (45.9 % of the butcheries) and burger patties (43.4 % of butcheries). Braaiwors had the highest production capacity (27.2 %), followed by boerewors (20.6 %), biltong (15.1 %), burgers (8.9 %); drywors (8.5 %) and viennas (5.1 %). The sodium compounds, identified from commercial spice pack labels, of the top six processed meat products included sodium chloride and sodium sulphide (used in boerewors, braaiwors and burger patties), nitrates and nitrites (used in viennas), as well as a potassium (used in biltong and drywors).

Sodium content in processed meat samples
Table 4 indicates sodium levels of processed meats tested using ICP-AES and FAAS. Figure 4 (a, b, c) provides a summary of sodium concentration of processed meat products.
Figure 3: Processed meats produced by butchery size (number of pay-points)

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Figure 4: Comparison and correlation of sodium concentration 4(a) correlation of the mean Na⁺ concentrations using ICP-AES, 4(b) correlation of the mean Na concentrations using FAAS and 4(c) overall relation of Na concentrations between ICP-AES and FAAS

p<0.0001
From Figure 4, biltong had the highest mean concentration of total sodium (3040 mg/100 g by ICP-AES and 1293 mg/100 g by FAAS), followed by drywors (2207 mg/100 g by ICP-AES and 1004 mg/100 g by FAAS). When analysed with ICP-AES, 31.1 % (82/264) of samples did not comply with the 2019 target, and 46.6 % (123/264) did not comply with the 2020 legal limits. In contrast, when using FAAS for the same samples, 2.3 % (6/264) and 4.9 % (13/264) did not comply to the same sodium legal limits, respectively. It was evident the sodium levels were unlikely to be compliant when determined with ICP-AES than with FAAS because of the superior sensitivity of the ICP-AES compared to FAAS. In comparing, the sodium concentrations for the different products (Table 4), the mean results using ICP-AES (64.7 - 9201.3 mg/100 g) were significantly (p<0.0001) higher than those obtained with FAAS (35.4 - 2350.9 mg/100 g). In Figure 4, Figures 4(a) and 4(b) were significantly different (p<0.0001), while Figure 4(c) demonstrated there was a weak correlation between the two legally prescribed sodium testing methods.

The 2013 South African sodium reduction regulations became the first in. In 2016, 2017 and 2019 there was an amendment of the inception sodium limits, and in each of the amendments, there was a reduction or increase of sodium levels for selected processed meats. Enforcement of regulations is merely left to the under-resourced health authorities and consequently, relevant authorities lack enforcement engagements to monitor the regulations and also to create awareness [25]. There was sodium contained in various compositions used in processed meats during formulation for purposes such as preservation of flavour and colour, inhibiting microbial growth and maintaining quality.

Processed meat production
The findings of this study were similar to a study in butcheries in Ireland, where processed meat products, such as cured meats, dried and raw sausages and fermented sausages, were commonly produced [26]. Davids et al. [27] indicated that butcheries manufactured similar processed meats meat products across different outlets in urban cities.

Processed meat products analysis
To alleviate the health effects of high sodium intake, South Africa promulgated sodium reduction regulations in certain foodstuffs, including processed meats. A study by Peters and Dunford [28] reported that 90 % of uncured processed meats met the 2019 TSL, while just over 40 % of raw processed sausages met the 2019 TSL. Similarly, van der Veer discovered that processed meats that are dry salted showed the highest sodium content; biltong and drywors also had the highest total sodium concentrations [29]. Biltong and other processed meats (polony and ham)
are often used as fillings for sandwiches in school lunchboxes [30]; it is, therefore, important to regulate the reduction of sodium in biltong and drywors as well. Apart from setting legal requirements, other methods globally promoted to reduce sodium intake include product formulation, environmental changes and increasing consumer awareness regarding the health impacts thereof [31]. Other considerations that may influence these measures appear below.

Compliance to regulatory requirements: in this regard, it is worrying that the top six products were mostly non-compliant with regulatory requirements. This could be due to the fact they used pre-packed spice mixes containing sodium. Typically, butcheries used the step-by-step spice labelling instructions and therefore trusted the products would comply with the legal sodium levels. In terms of the South African Foodstuffs, Cosmetics and Disinfectants Act 54 of 1972, the responsibility however, still lies with the person in charge of a premises to ensure that “foodstuff manufactured, kept or sold from the premises complies in all respects to the provisions of the Act and the regulations promulgated thereunder, including the labelling thereof.” That implies that measurement, as an act of determining total sodium levels in processed meat products must be carried out.

Risk identification and assessment: the assessment of risk could be the best tool of identification, evaluation and control of the use of sodium and sodium containing spice mixes during production of processed meats. For example, Food Safety Management Systems, such as ISO 22000 [32], require food processors to maintain information of raw materials to the extent needed to conduct a hazard analysis, including chemical characteristics (for example sodium content); as well as the identification of legislation related to the composition of end products. In addition, processed meats manufacturing organisations must identify the risk associated with food safety hazards that can reasonably be expected to occur due to raw materials and product ingredients. This would include high-levels of sodium in prepacked and processed meat as it has the potential to cause chronic adverse health effects for the consumer.

Sodium test method(s): the fact that the sodium results of the two sodium testing methods, legislated by the South African sodium reduction regulations significantly differ, could create misleading and/or inaccurate sense of compliance. It was for this reason that the ICP-AES replaced the use of FAAS in determining certain food trace elements due to longer linear ranges, higher sensitivity and speed of this method compared to others [33]. With the outcome of this study, the South African law makers and legislators should consider further investigation to determine an
alternative sodium testing method to be legislated whose sodium results can be comparable to the ICP-AES.

Declaration of sodium level in prepacked spices: declaration of ingredients has been part of labelling requirements in South Africa in all foodstuffs. In this instance, it is essential there is quantifying and labelling of the sodium content of the prepacked spices for use in processed meat formulation, for guidance.

Cost of testing sodium: in 2018, Taylor and colleagues listed costs as one of the challenges the food industry faces in reducing sodium [34]. In the case of local butcheries, routine analysis may not be cost effective when using the two legally prescribed methods, namely the FAAS and ICP-AES. It is therefore urgent to find an affordable and easy-to-use alternative test method for total sodium that butcheries can use on-site on a routine basis.

Bacterial growth: as a matter of consideration, reduction of sodium may have an impact on processed meats bacterial growth. Spoilage microorganisms will typically affect the palatability of biltong and its shelf life. In addition, moulds may produce mycotoxins that may have an influence on the health of consumers when consumed in the product [35].

Training of manufacturing and reformulating operators: training of manufacturers is essential in the control of sodium content in processed meat. In this regard, the South African legislation clearly specifies that a person in charge of food premises must ensure that he or she, and any other person working as a food handler in their food premises, is suitably qualified or otherwise adequately trained in the principles and practices of food safety and hygiene, as appropriate, and that there are routine assessments conducted to determine the impact of the training [36].

CONCLUSION

Globally the consumption of sodium dense processed food (including meats) has increased. For this reason, the global trend is to create awareness in populations and propose sodium reduction strategies to reduce sodium consumption and increase consumer awareness. In relation to the South African strategy, the study revealed areas of constraint, in particular local butcheries that manufacture their own products with ready-to-use spices. The study demonstrated that sodium content in processed meats produced by local butcheries in the CoT was higher than the legislated benchmarks for the analysed products. It was also clear that the targeted timeframes to reduce the total sodium content in these products would not
be met. Even though the sodium reduction regulations exist and are current, there is a lack of enforcement by the authorities to control sodium levels in processed meats produced by local butcheries, and to create feasible sodium reduction strategies at that level. Legislators should consider regulating biltong and drywors sodium limits as processed meat products, due to the probable high levels of total sodium content in these products and the fact they are a popular snack in South Africa. Furthermore, because of the significant differences in the sodium concentration results obtained between FAAS and ICP-AES, it is advisable to revisit these in an attempt to find testing methods whose sodium concentration results could be comparable with ICP-AES or replace the FAAS as it is less sensitive and there could be misleading complying results obtained. Health authorities must put more effort into informing local butchery owners in different media of the sodium reduction strategies, and encourage them to become “agents of change” who can promote the national sodium reduction philosophy amongst their customers.

Ethics Statement
The Tshwane University of Technology (TUT), Faculty of Science Committee for Research Ethics granted ethical approval (Reference number FCRE2016/07/005(2)(SCI).

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Authors’ contributions
EJM was responsible for the study preparation, design, coordinating, data collection and analysis and drafted the manuscript. JLB and NSM were responsible for conceptualising the study, technical advice, guidance and editing of the manuscript. All authors have read and approved the manuscript.

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Availability of data and materials
The data sets analysed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare they have no competing interests.
Table 1: Summary of meat related categories as per sodium reduction regulation [20,37]

<table>
<thead>
<tr>
<th>Category description</th>
<th>Class description</th>
<th>Description and examples</th>
<th>South African TSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 7: Processed meat products in class 5 relates to cured</td>
<td>Class 1: Comminuted, cured, heat treated products</td>
<td>Emulsion products (polonies, viennas)</td>
<td>1300 mg</td>
</tr>
<tr>
<td></td>
<td>Class 4: Reformed, cured, heat treated</td>
<td>Reformed hams, chicken, turkey rolls</td>
<td>1150 mg</td>
</tr>
<tr>
<td></td>
<td>Class 5: Unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category 8: Processed meats in class 5 relates to uncured</td>
<td>Class 2: Comminuted, uncured, heat-treated products</td>
<td>Blanchied pork sausages, uncured chicken viennas, polonies, fully cooked burgers</td>
<td>850 mg</td>
</tr>
<tr>
<td></td>
<td>Class 3: Reformed, uncured, no partial heat-treated products</td>
<td>Reformed nuggets, schnitzels</td>
<td>650 mg</td>
</tr>
<tr>
<td></td>
<td>Class 5: Unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category 9: Raw - processed meat sausages (all types) and similar products</td>
<td>Class 5: Unspecified</td>
<td>Braaiwors (standard grade sausage), boerewors (quality sausage)</td>
<td>800 mg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>600 mg</td>
</tr>
</tbody>
</table>

mg = milligram  
TSL = Total Sodium Limits
Table 2: Proportional selection of local butcheries in the seven regions of the CoT

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Regions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6  7</td>
<td></td>
</tr>
<tr>
<td>Butcheries on CoT database (N)</td>
<td>41  46  71  68  12  79  8</td>
<td>325</td>
</tr>
<tr>
<td>Sample size statistically determined</td>
<td>20  20  35  35  5  40  5</td>
<td>160</td>
</tr>
<tr>
<td>Actual sample size (n)</td>
<td>16  18  27  23  5  30  3</td>
<td>122</td>
</tr>
<tr>
<td>Actual sample size (%)</td>
<td>39  39  38  34  42  38  38</td>
<td>38</td>
</tr>
</tbody>
</table>

Note: The deviation from the statistically determined sample size was influenced by the fact that the butchery database was outdated and some butcheries preferred not to partake in the study.

CoT = City of Tshwane

Table 3: Butchery distribution across the regions where there were samples taken

<table>
<thead>
<tr>
<th>Sample size determination</th>
<th>Regions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6  7</td>
<td></td>
</tr>
<tr>
<td>Butcheries per region</td>
<td>9  9  14  13  3  15  3</td>
<td>66</td>
</tr>
<tr>
<td>Number of meat samples</td>
<td>54  54  84  78  18  90  18</td>
<td>396</td>
</tr>
<tr>
<td>(Six samples / butchery)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samples per region (%)</td>
<td>13.6  13.6  21.2  19.7  4.5  22.7  4.5</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 4: Sodium levels of processed meats tested using ICP-AES and FAAS

<table>
<thead>
<tr>
<th>Top six sampled Products</th>
<th>No. of samples per product</th>
<th>ICP-AES (mg/100 g)</th>
<th>FAAS (mg/100 g)</th>
<th>Comparison between means of ICP-AES and FAAS (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2019</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>Boerewors</td>
<td>66</td>
<td>74.3</td>
<td>2038</td>
<td>327</td>
</tr>
<tr>
<td>Burger Patties</td>
<td>66</td>
<td>64.7</td>
<td>4912</td>
<td>617</td>
</tr>
<tr>
<td>Braaiwors</td>
<td>66</td>
<td>195</td>
<td>2973</td>
<td>432</td>
</tr>
<tr>
<td>Vienna</td>
<td>66</td>
<td>471</td>
<td>2859</td>
<td>410</td>
</tr>
<tr>
<td>Drywors</td>
<td>66</td>
<td>319</td>
<td>3869</td>
<td>648</td>
</tr>
<tr>
<td>Biltong</td>
<td>66</td>
<td>614</td>
<td>9201</td>
<td>1466</td>
</tr>
</tbody>
</table>

Notes: NA = Not applicable. The inclusions of dried products in the 2013 regulations and later the excluded in the 2017 amendment to the regulations

ICP-AES = Inductively Coupled Plasma Atomic Emission Spectrometry
FAAS = Flame Atomic Absorption Spectroscopy
ANOVA = A one-way analysis of variance
df = degrees of freedom
SD = Standard deviation

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