Journal of Food Composition and Analysis 143 (2025) 107476

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Nutrient value and density of South African processed meat

Beulah Pretorius *, Carmen Muller, Hettie C. Schönfeldt

Department of Animal Science, University of Pretoria, Pretoria, South Africa

ARTICLE INFO

Keywords:
Processed meat
Nutrient density
Cost of nutrients
Protein
Sodium regulations

ABSTRACT

There has been a significant rise in processed meat consumption in South Africa, yet no previous studies have assessed the nutrient density of country-specific processed meats. This study analysed eight processed meat products: tinned corned beef, tinned meatballs, hamburger patties, frozen beef sausages, French and chicken polony, red and chicken viennas, focusing on their nutrient density and nutrient-to-price ratio. The energy content varied from 447 kJ/100 g to 1020 kJ/100 g in tinned meatballs and frozen beef sausages, respectively. Protein content ranged from 8.31 g/100 g in tinned meatballs to 15.9 g/100 g in hamburger patties, lower than in red meat. Fat content was 3.69 g/100 g in tinned meatballs to 17.9 g/100 g in frozen products. Saturated fat constituted 30–50 % of total fat, monounsaturated fat 35–47 %, and polyunsaturated fat 3–25 %. Trans-fat levels were within regulatory limits. Iron content was highest in corned beef at 3.61 mg/100 g, and zinc was highest in hamburger patties at 2.86 mg/100 g. Over 80 % of products met sodium reduction targets. Nutrient profiling indicated tinned meatballs, French polony, and hamburger patties offer the best nutritional value per cost. Processed meats can provide protein, iron, and zinc, but consumer education on the benefits of lean meats and moderate processed meat consumption remains important.

1. Introduction

Food impacts human health and the environment in a variety of ways, ranging from positive to negative. In sub-Saharan Africa (SSA), both food systems and dietary patterns are undergoing rapid changes due to urbanisation, increased income, and employment changes, leading to a transformation in the epidemiology of the burden of malnutrition. Over the past few decades, overweight and obesity have added to the pre-existing high rates of stunting and wasting in children, as well as extreme underweight in women of childbearing age. Collectively, these issues have given rise to a dual challenge of malnutrition, often referred to as the double burden of malnutrition (Popkin et al., 2020). However, increased participation in work outside the home has led more people to opt for processed food and dining out to reduce the labour-intensive tasks of home food processing and preparation (Reardon et al., 2021). Processed food undeniably plays a significant role in modern diets, particularly in urban areas. Processed foods save time, with additional, often overlooked advantages, such as safeguarding against post-harvest losses and guaranteeing year-round food accessibility. The popularity of processed meat can be ascribed to its affordability, adaptability, extended shelf-life, and widespread availability in the marketplace, (Madlala et al., 2023; Michel et al., 2024; Reardon et al., 2021). In 2018, the estimated dietary consumption (g/day) of processed meat among children and adults in sub-Saharan Africa and South Africa was 12 and 17 g/day, respectively. Although this is lower than reported for Central or Eastern Europe (54 g/day) and Latin America and the Caribbean region (37 g/day), it is in line with the reported processed meat consumption for the world (17 g/day) (Miller et al., 2022). In lower-income countries such as Ethiopia, the daily processed meat intake was higher than the unprocessed meat intake (Miller et al., 2022; Ronquest-Ross, 2016). Processed meat is often the only meat consumed in a low-income household. It is reported by Godbharle et al. (2024) that approximately 15–35 % of the South African population reported consuming processed meat at least once a week, while nearly 12 % of participants stated they eat processed meat daily. It is projected that the processed meat market in South Africa will experience further growth to meet the rising needs of an expanding population with the poorer economic quantiles having greater exposure to processed foods (Godbharle et al., 2024).

Various factors influence the impact of foods on health, and one of these factors is their significance within dietary patterns. The increasing demand for affordable animal protein and preference for convenience is expected to grow the processed meat market even further. An essential consideration is the nutritional density of processed foods (nutrients per

* Corresponding author.
E-mail address: beulah.pretorius@up.ac.za (B. Pretorius).

https://doi.org/10.1016/j.jfca.2025.107476
Received 12 September 2024; Received in revised form 5 March 2025; Accepted 9 March 2025
Available online 27 March 2025

unit of energy) and their energy density (energy per volume). Frequently consumed foods with low nutritional density, such as those lacking in protein, minerals or vitamins; and high energy density, such as those high in sugar, saturated fat or high in sodium, can disrupt the dietary balance. This disruption can result in either nutritional deficiencies or the development of chronic diseases like obesity, dyslipidemia, hypertension, or sometimes a combination of both (Holmes et al., 2018; Monteiro, 2009). Consumption of processed meats is reported to be the second largest contributor to total dietary sodium intake in South Africa (Charlton et al., 2005). Therefore, the Department of Health implemented a salt reduction programme, assisted by legislation, to reduce the levels of sodium/salt found in processed foods (including processed meat products) in South Africa (South African National Department of Health, 2013).

High-quality food composition data are indispensable for improved decision-making in food security, health policy formulation, food labelling, diet formulation, agricultural policymaking, nutrition research, and many other nutrition-related activities. The optimisation of dietary patterns is a powerful tool to reduce the impact of malnutrition on a population's health and well-being, However, of all the food items found in the Food Composition Tables for South Africa, only 13 processed meat items are listed in the tables with data borrowed from the American Food Composition Tables. None of the data for processed meat products is of South African origin.

This project aimed to describe both ready-to-eat (RTF) (ie. Tinned corned beef, Tinned meatballs, French and Chicken polony and Red and Chicken viennas) and frozen (ie. Frozen hamburger patties and Frozen beef sausages) processed meat products in terms of nutrient density, and cost/nutrient value. As processed meat is often produced using slaughter byproducts, animal fat and offal, it is hypothesised that processed meat products will have a lower nutrient density, but a higher cost-to-nutrient value ratio compared to beef and chicken meat.

2. Materials and methods

2.1. Sampling and sample preparation

The sampling focussed on processed meat products aimed at the middle- and low-income segment of the population. The identified samples (eight different products) were sourced, as purchased by consumers, from 7 different retail outlets in 2021/2022. Two samples of each brand with different manufacturing dates (ie. tinned corned beef (n = 8 brands), tinned meatballs (n = 3 brands), hamburger patties (n = 6 brands), frozen beef sausages (n = 4 brands), French polony (n = 5 brands), chicken polony (n = 6 brands), red viennas (n = 5 brands) and chicken viennas (n = 6 brands) were randomly sampled from different outlets. Samples were homogenised, coded to ensure anonymity and stored at $< 4^{\circ}$C until it was transported to the laboratory for analyses within one week after sampling. All samples were sent to the laboratory in duplicate for nutrient analyses. Upon arrival at the laboratory, each sample was freeze-dried and milled to ensure homogeneity of the sample.

Method validations were done in-house by the laboratory according to accreditation requirements (ISO/IEC 17025:2017). Accuracy of the protein, fatty acid, and mineral analyses was evaluated using an appropriate certified reference material (CRM). An industrial control sample was analysed with each batch of samples. The laboratory participated in proficiency testing programs organised by the Agri-Laboratory Association of Southern Africa (AgriLASA) and the Bureau Interprofessionnel d'Études Analytiques (BIPEA), and conducted inter-laboratory comparison studies with three independent laboratories in South Africa.

2.2. Analytical methodology

2.2.1. Proximate analyses of selected processed meat samples

Analyses for crude protein, moisture, ash and crude fat were done by LabWorldSA, Johannesburg, South Africa. The details and references for each method of analysis can be found in Table 1.

2.2.2. Fatty acid profile and cholesterol

Determination of the fatty acid profile was done according to the official analysis method AOAC 996.06 (AOAC, 2000). The samples were hydrolysed using hot concentrated hydrochloric acid, followed by extraction with a mixture of petroleum and diethyl ether. The fat fractions were trans-methylated with methanol-potassium hydroxide. The fatty acid methyl esters (FAME) were extracted with n-hexane and analysed using gas chromatography with flame ionisation detection (GC-FID) (Shimadzu GC-2010) equipped with a SP®-2560 Capillary fused silica column (100 mx 0.25 mm×0.2 μm) (Sigma-Aldrich). Undecanoic acid (C11:0) was used as an internal standard.

Cholesterol content determination was done according to the official analysis method AOAC 976.26 (AOAC, 1996). Lipid extraction from the sample was done using mixed solvents; followed by saponification with methanolic potassium hydroxide. The unsaponifiable fraction containing cholesterol and other sterols was extracted with benzene and derivatised to form trimethylsilyl (TMS) ethers which were determined quantitatively by gas chromatography with flame ionisation detection (GC-FID) (Shimadzu GC-2010, Kyoto, Japan) equipped with a SP®-2560 Capillary fused silica column (100 mx 0.25 mm×0.2 μm) (Sigma-Aldrich, Johannesburg, South Africa). 5α-cholestane was used as an internal standard.

2.2.3. Mineral analyses

Minerals (iron, zinc and sodium) were determined using the AOAC Official Method 942.05 (AOAC, 2005) and Official Method 984.27 (AOAC, 2007), optimised and validated by the laboratory (Poitevin, 2012). Samples were ashed for at least three hours at 550 °C followed by acid digestion. Samples were then analysed using an inductively coupled plasma optical emission spectroscopy (ICP-OES) (Avio® Max ICP-OES, PerkinElmer, Midrand, South Africa), using an acidified calibration range to determine the sodium concentration.

2.2.4. Evaluation of the energy and nutrient density

Nutrient density is defined as the ratio of nutrient content to total energy. The nutrient density of each product was evaluated using the nutrient-rich foods (NRF) model proposed by Drewnowski (Drewnowski et al., 2019; Fulgoni et al., 2009) taking into consideration a broader array of nutrients rather than a singular nutrient. The NRFn.3 model is based on a variable amount of nutrients to encourage and three nutrients to limit (LIM) (Table 2). The LIM are always the same: saturated fat, added sugar (or total sugar) and sodium, whereas the number of nutrients to encourage is variable (n = 6–15). Indices were calculated as "the sum of nutrients to encourage minus the sum of LIM based on 100 g and 100 kcal (418 kJ)" (Eqaution 2).

$$Energy\ density(kcal\Big/100g) = \div\frac{Energy(kJ/100g)}{418} \quad (1)$$

$$NRF9.3score = \frac{\left(\sum_{i=1}^{9}\frac{Nutrient_i}{NRV_i}x \quad 100\right) - \left(\sum_{j=1}^{3}\frac{LIM_j}{MRV_j}x \quad 100\right)}{Energy\ density} \quad (2)$$

Nutrients that should be encouraged in the diet are either due to their functionality or due to their general lack from diets. For this study, within the South African context, the selected nutrients to encourage were protein, dietary fibre, calcium, iron, zinc, vitamin A, Vitamin B2, vitamin B6 and vitamin B12. These nutrients were identified as nutrients

Table 1
Methods of analyses and validation parameters for crude protein, moisture, ash and crude fat.

Nutrient	Principle	Limit of Detection (LoD)	Repeatability (%RSD)	Reproducibility (% RSD)	Uncertainty (%)
Moisture	Moisture was gravimetrically determined after it had been dried in an oven at 105 ± 1 ∘C for 16 h. Weight loss is used to calculate dry matter content. Gravimetric method – AOAC 934.01 (AOAC, 2000B)	0.02 %	1.55	2.01	0.03
Ash (inorganic fraction)	Ash represents the mineral content of a sample after carbon, oxygen, sulphur and water have been driven off during combustion in a furnace at 560–600̊C. Gravimetric method - AOAC 942.05 (AOAC, 2005)	0.04	2.55	2.89	0.04
Crude protein (CP)	Total nitrogen is measured as nitrogen gas after the complete combustion of the sample using a FP828 LECO protein analyser (Michigan, USA). A nitrogen to protein conversion factor of 6.25 was used. Dumas-method - AOAC 992.15 (AOAC, 2000d)	1.25	1.28	2.89	0.04
Crude fat	Hydrolysed with concentrated hydrochloric acid in a water bath with boiling water (3 hr) followed by extraction with petroleum ether using a Soxtherm (Gerhardt, Germany). (AOAC 922.06, 954.02) (AOAC, 2000a, 2000c)	0.07	3.55	2.15	0.98
Fatty Acid Profile	Hydrolysed using hot concentrated hydrochloric acid, followed by extraction with a mixture of petroleum and diethyl ether and quantification with GC-FID	0.01 for all fatty acids	0.55 – 3.55 depending on concentration	1.05 – 5.48 depending on concentration	0.06
Minerals	Ashing, acid digestion and quantification with ICP-OES	0.01–0.03 % for major elements. 0.08–0.11 mg/kg for minor elements	2.15–5.15 % for major elements depending on concentrations. 1.15–5.84 % for minor elements depending on concentrations	1.55–6.5 % for major elements depending on concentrations. 3.55–7.01 % for minor elements depending on concentrations	0.98–1.85 % for major elements depending on concentrations. 2.11–4.58 % for minor elements depending on concentrations
Carbohydrates (calculated)	Residual weight after subtracting amounts of moisture, protein, fat, and ash found by analysis (Greenfield and Southgate, 2003).				
Energy (calculated)	The Atwater general energy conversion factors were used, *ie.* 17 kJ/g for protein, 37 kJ/g) for fat and 17 kJ/g for carbohydrates (Greenfield and Southgate, 2003).				

Table 2
Nutrient reference values (NRVs) and maximum recommended values (MRVs) for selected nutrients.

Nutrients to encourage	**NRV** (Lewis, 2019)
Protein (g)	50
Fibre (g)	25
Vitamin A (μg RE)	800
Vitamin B2 (mg)	1.2
Vitamin B6 (mg)	1.3
Vitamin B12 (μg)	2.4
Calcium (mg)	1 000
Iron (mg)	22
Zinc (mg)	14
Nutrients to limit	**MRV** (Vorster et al., 2013)
Saturated fat (g)	22
Total sugar (g)	50
Sodium (mg)	2 000

lacking in the South African diet (Labadarios et al., 2005). Missing values for calcium, vitamin A, riboflavin, vitamin B6 and vitamin B12 were calculated by taking into account the percentage of moisture and fat in the analysed data. For missing micronutrient values, food matching was done as per the INFOODS guidelines (FAO, 2011) between the analysed data, the South African Food Composition Tables (SAFOODS, 2017), USDA Food and Nutrient Database (USDA, 2022), Dutch Food Composition Database (NEVO, 2023) and McCance & Widdowson's dataset (Public Health England, 2021). The nutrient reference values (NRVs) were based on the FAO Codex NRVs for the general population of individuals older than 36 months (Lewis, 2019). Maximum recommended values (MRVs) for the nutrients to limit in the South African population according to the South African Food Based Dietary Guidelines is calculated as 10 % of energy intake each for added sugar and saturated fat based on an 8 400 kJ/day diet, and 5 g/day of salt (Vorster et al., 2013). NRVs and MRVs are summarised in Table 2.

2.2.5. *Evaluation of the cost of nutrients*

The nutrient-to-price ratio (NPR) was used as a measure to identify foods offering the best nutritional value for their cost. It was calculated by dividing the NRF9.3 score by the cost in ZAR per 100 g and per 100 kcal of the food. For comparison, the NPR of raw C-age beef and raw chicken (including meat and skin) were also evaluated.

Data used for the evaluation:

- NRF9.3 values analysed in this study for processed meat (Table 5).
- The current rand value for the different products was obtained from retailers. Retail prices for the food items were obtained online from the national websites of six national supermarkets. Prices were collected in October 2023. Only regular prices were recorded, no sale/promotional pricing.

2.2.6. *Data analysis*

Data were captured into Microsoft Excel and descriptive statistics and calculations were done using Microsoft Excel functions. Statistical analysis was conducted using GenStat for Windows (2008) software (Payne et al., 2009). The significance of all variables measured for each sample was tested using a one-way analysis of variance (ANOVA). The differences between products were tested with a Fisher's protected *t*-test least significant difference at the 1 % level of significance as the variances were not homogeneous.

3. Results and discussion

3.1. Nutrient profile of selected processed meats

Nutrient profiling evaluates and classifies foods based on their nutritional composition, such as vitamins, minerals, fats, and sugars, to guide healthier dietary choices. A balanced diet meets energy and nutrient needs, supporting health, well-being, and optimal growth (FAO, IFAD, UNICEF, WFP, and WHO, 2024).

The energy and proximate content (protein, fat, moisture, ash and carbohydrate) content of the eight selected processed meat products are reported in Table 3. For all the products in the study, the dietary fibre < 1.0 g/100 g and total sugars < 0.5 g/100 g were lower than the quantification limit of the laboratory and will therefore not be discussed. For comparison the raw and cooked nutrient values for both beef (C-age) and chicken (meat and skin) are also provided in Table 4. The ready-to-eat (RTE) (polonies, viennas and tinned products) can be compared with the cooked meat and the frozen products (hamburger patties and beef sausages) can be compared with the raw meat.

3.1.1. Energy

The recommended amount of energy needed in a diet frequently varies based on factors such as a body weight and and activity level. Energy intake should be in balance with energy expenditure. While fats and carbohydrates primarily supply dietary energy, proteins can also contribute to energy intake. The dietary energy content of the eight processed meat products evaluated in this study ranged from the lowest 447 kJ/100 g for tinned meatballs to the significantly higher 987 kJ/100 g and 1020 kJ/100 g for the hamburger patties and the frozen beef sausages, respectively. There was no significant difference in energy between the four emulsion products: French and chicken polony, and red and chicken viennas. The RTE products were reported to have a lower energy content than the cooked/boiled meat, while the frozen products have a similar energy content to the raw beef and a higher content than the raw chicken.

3.1.2. Protein

Adequate dietary protein is important for individuals during all stages of life. According to the World Health Organization (WHO), dietary protein intake in developing countries falls significantly short of the recommended 0.8 g/kg body weight per day for adults < 65 years (FAO, 2013; Nunes et al., 2022). This translates to approximately 56 g of protein for a person with an average weight of 70 kg. The dietary protein content of the processed meat products evaluated in this study ranged from 8.31 g/100 g (tinned meatballs) to 15.9 g/100 g (hamburger patties). This is lower than the raw and cooked beef and chicken as seen in Table 4. A 100 g of processed meat in this study can provide between 15 % and 28 % of protein requirements.

3.1.3. Fat and cholesterol content

In recent years, a significant amount of consumers have become more informed and more focused on the food they eat. These concerned consumers are more critical of the quality and quantity of fat in their diet (Vermeulen et al., 2015). When evaluating the quality of fats in the diet, the three most characteristic effects of fats in animal-derived products are the increased amount of saturated- and trans-fat and cholesterol (Astrup et al., 2020). Nevertheless, consuming diverse diets and appropriate levels of animal-sourced foods can provide the necessary ratios of essential fatty acids (linoleic to α-linolenic acids) and enable the absorption of fat-soluble vitamins needed for human health. Dietary intakes of long-chain fatty acids are important for brain development and cognition across the life course (FAO, 2023).

Dietary fat content in the processed meat products ranged from as low as 3.69 g/100 g in the tinned meatballs to 17.9 g/100 g in the frozen products (hamburger patties and sausages). The saturated fat in all the analysed products is on average between 40 % and 50 % of the total fat for the corned beef, tinned meatballs and frozen beef sausages. For the remainder of the products, the average % saturated fat is between 30 % and 40 %. The monounsaturated fat ranges from 35 % to 47 % and polyunsaturated fat between 3 % and 25 % of total fat. Earlier observational research has associated saturated fat with a higher likelihood of cardiovascular diseases and diabetes. Yet, newer studies suggest this connection might have been influenced by industrial trans fatty acids (TFA) found in for example margarine. A high intake of industrial TFAs has been linked to an increased risk of chronic disease (Astrup et al., 2020). According to Codex trans fatty acids are defined as "all the geometrical isomers of monounsaturated and polyunsaturated fatty acids having non-conjugated, interrupted by at least one methylene group, carbon-carbon double bonds in the trans configuration (Codex Allimentarius, 2021). Therefore, all conjugated linoleic acids (CLAs) are excluded. Four of the processed meat products (corned meat, tinned meatballs, hamburger patties and frozen beef sausages) contained between 3 % and 4 % trans fatty acids (<1 g trans-fat/100 g product), while the trans fats in the other four products (French and chicken polony and red and chicken viennas) were < 1 % trans fats (<0.1 g/100 g product) (which is below the quantification limit). This complies with the regulations (R.127) relating to trans-fat in foodstuffs whereby a claim that a foodstuff is "Trans-Fat free" can be made on the label or in an advertisement if the content of trans-fat is less than 1 g per 100 g of the total fat or oil in the final product (South African National Department of Health, 2011).

The World Health Organization (WHO) advises that total fat intake should stay below 30 % of total energy intake to prevent unhealthy weight gain. Adults and children are recommended to limit saturated fat, to no more than 10 % of their daily energy intake and to consume less than 1 % of trans fats to lower the risk of heart disease (Astrup et al., 2020; WHO, 2023). According to the European Food Safety Authority (EFSA), trans fatty acids are neither synthesised nor required and do not serve any vital functions in the human body. Consequently, there are no established Population Reference Intake, Average Requirement, or Adequate Intake values (European Food Safety Authority (EFSA), 2015). While a definitive link between animal fat and cardiovascular disease is not established (FAO, 2023), heightened public awareness about obesity and non-communicable diseases has amplified the focus on reducing the consumption of saturated and trans fats and replacing them with polyunsaturated fat (Heileson, 2020).

Another significant lipid compound is cholesterol, synthesised in the liver and present in animal source foods. Cholesterol plays a crucial role in the human body, contributing to cell membrane function and stability while serving as a precursor for essential steroids like sex hormones, adrenocortical hormones, and vitamin D. HDL (High-Density Lipoprotein) and LDL (Low-Density Lipoprotein) cholesterol are types of lipoproteins used to transport cholesterol in human blood. The balance between high-density lipoprotein and low-density lipoprotein has a significant impact on human health. Excess LDL causes plaque buildup, increasing cardiovascular disease (CVD) risk, while HDL removes LDL, transporting it to the liver for excretion. (CDC (Centers for Disease Control and Prevention), 2024). Despite some uncertainty regarding the relationship between dietary cholesterol intake levels and LDL cholesterol, dietary cholesterol has been implicated as a risk factor for cardiovascular disease, potentially due to the correlation with saturated fat intake (Zampelas & Magriplis, 2019). An excess of cholesterol might not undergo easy catabolism, potentially heightening the risk of atherosclerosis.

Dietary cholesterol content in the processed meat products ranged

Table 3
Proximate, fatty acid profile, cholesterol and mineral content of eight selected processed meat products.

Product Brand	Moisture (g/100 g)	Ash (g/100 g)	Energy (Calculated) (kJ/100 g)	Protein (g/100 g)	Carbohydrates (Calculated) (g/100 g)	Total Fat (g/100 g)	Saturated Fat (g/100 g)	Trans Fat (g/100 g)	Cholesterol (mg/100 g)	Sodium (g/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Tinned corned beef												
Brand A	71.8 ± 0.21	2.58 ± 0.11	559 ± 3	14.8 ± 14.8	4.66 ± 0.06	6.17 ± 0.15	3.15 ± 0.14	0.25 ± 0.06	26.6 ± 4.81	1.28 ± 0.85	5.25 ± 3.02	4.40 ± 2.27
Brand B	65.0 ± 0.03	3.00 ± 0.01	811 ± 16	10.8 ± 0.05	7.94 ± 0.88	13.3 ± 0.82	6.38 ± 0.32	0.45 ± 0.01	40.2 ± 18.4	1.38 ± 0.69	2.67 ± 1.18	2.26 ± 1.56
Brand C	64.3 ± 1.32	3.03 ± 0.07	841 ± 37	10.9 ± 0.01	7.53 ± 0.74	14.3 ± 0.67	7.85 ± 0.45	0.58 ± 0.00	26.3 ± 2.38	0.885 ± 0.02	2.98 ± 0.06	1.11 ± 0.21
Brand J	65.7 ± 0.84	3.25 ± 0.01	793 ± 24	10.9 ± 0.2	6.88 ± 0.51	13.3 ± 0.52	6.09 ± 0.09	0.44 ± 0.13	34.4 ± 5.27	1.79 ± 0.18	4.43 ± 1.59	1.83 ± 0.05
Brand L	69.1 ± 0.37	3.09 ± 0.01	642 ± 11	11.60.08 ±	7.77 ± 0.06	8.44 ± 0.22	3.72 ± 0.03	0.16 ± 0.05	21.0 ± 8.86	1.54 ± 0.01	4.48 ±0.55	3.79 ± 1.96
Brand O	67.2 ± 3.07	2.76 ± 0.28	747 ± 105	10.9 ± 0.5	7.39 ± 0.59	11.8 ± 2.88	6.23 ± 1.45	0.40 ± 0.22	20.3 ± 2.16	0.800 ± 0.03	2.35 ± 0.16	1.14 ± 0.12
Brand P	64.4 ± 0.10	2.89 ± 0.11	819 ± 17	10.2 ± 0.14	9.27 ± 1.00	13.2 ± 0.85	7.00 ± 0.41	0.49 ± 0.01	22.7 ± 1.17	0.880 ± 0.00	2.41 ± 0.86	1.27 ± 0.14
Brand R	67.8 ± 2.74	2.98 ± 0.13	721 ± 92	11.4 ± 0.25	6.65 ± 0.97	11.2 ± 2.16	4.91 ± 0.94	0.34 ± 0.10	37.6 ± 6.94	1.68 ± 0.20	4.33 ± 0.27	2.25 ± 0.73
Mean±SD	**66.9[bc] ± 2.73**	**2.95 ± 0.22**	**741[b]± 102**	**11.4[e] ± 1.39**	**7.26 ± 1.37**	**11.5[b] ± 2.89**	**5.67[a] ± 0.49**	**0.388[b] ±0.07**	**28.6[c]± 9.55**	**1.28[a]± 0.47**	**3.61[a] ± 1.46**	**2.26[a]± 0.10**
Tinned meatballs												
Brand A	77.1 ± 1.26	1.67 ± 0.01	425 ± 33	9.26 ± 0.19	8.87 ± 0.51	3.16 ± 0.57	1.62 ± 0.13	0.133 ± 0.02	10.7 ± 0.56	0.460 ± 0.01	1.91 ± 0.26	1.7 ± 0.14
Brand B	76.4 ± 0.47	2.23 ± 0.13	437 ± 7	7.69 ± 0.07	9.97 ± 0.20	3.69 ± 0.06	1.69 ± 0.42	0.095 ± 0.06	9.43 ± 1.26	0.600 ± 0.01	1.97 ± 0.11	0.95 ± 0.15
Brand J	74.5 ± 1.18	2.36 ± 0.22	478 ± 22	7.98 ± 0.35	11.0 ± 0.35	4.21 ± 0.27	1.74 ± 0.06	0.100 ± 0.02	9.59 ± 3.42	0.570 ± 0.03	1.71 ± 0.14	0.93 ± 0.09
Mean±SD	**76.0[a] ± 1.45**	**2.08 ± 0.35**	**447[c]± 31**	**8.31[f] ± 0.77**	**9.95 ± 0.99**	**3.69[c] ±0.55**	**1.68[c] ± 0.21**	**0.112[c] ± 0.04**	**9.89[d] ± 1.76**	**0.543[c]± 0.07**	**1.86[bc] ± 0.19**	**1.2[b]± 0.39**
Hamburger patties												
Brand A	69.4 ± 6.63	1.18 ± 0.13	781 ± 169	16.6 ± 0.40	-	14.1 ± 2.91	5.19 ± 1.02	0.680 ± 0.27	42.3 ± 7.67	0.240 ± 0.03	2.60 ± 0.21	2.67 ± 0.09
Brand G	63.7 ± 4.32	2.43 ± 0.10	937 ± 263	16.7 ± 0.81	-	18.1 ± 9.41	6.98 ± 2.13	0.300 ± 0.17	43.5 ± 2.56	0.530 ± 0.08	2.77 ± 0.81	2.69 ± 0.65
Brand I	57.0 ± 0.20	5.93 ± 0.01	950 ± 11	12.3 ± 0.18	8.76 ± 0.34	16.0 ± 0.37	8.50 ± 0.54	0.983 ± 0.11	27.2 ± 1.82	0.490 ± 0.01	3.79 ± 0.55	1.93 ± 0.01
Brand J	53.6 ± 0.34	2.42 ± 0.01	1074 ± 283	14.5 ± 0.37	13.2 ± 14.1	16.3 ± 14.45	5.64 ± 2.86	0.535 ± 0.29	44.7 ± 4.53	0.685 ± 0.09	2.27 ± 0.37	2.27 ± 0.21
Brand K	60.2 ± 3.32	0.845 ± 0.11	1084 ± 139	18.2 ± 1.01	-	21.1 ± 4.24	3.98 ± 0.53	0.258 ± 0.05	49.0 ± 8.00	0.070 ± 0.00	4.60 ± 2.68	3.73 ± 0.45
Brand Q	60.3 ± 0.21	0.690 ± 0.06	1098 ± 10	16.9 ± 0.06	0.375 ± 0.28	21.7 ± 21.7	7.83 ± 0.56	0.560 ± 0.06	65.6 ± 6.72	0.160 ± 0.13	2.89 ± 0.34	3.84 ± 0.11
Mean±SD	**60.7[de] ± 5.83**	**2.25 ± 1.87**	**987[a]± 178**	**15.9[a] ± 2.06**	**3.31 ± 7.46**	**17.9[a] ± 6.15**	**6.35[a] ± 2.01**	**0.553[a] ± 0.29**	**45.4[ab] ± 12.55**	**0.363[c]± 0.24**	**3.16[ab] ± 1.21**	**2.86[a]± 0.78**
Frozen beef sausages												
Brand A	61.5 ± 1.32	1.94 ± 0.09	918 ± 57	15.1 ± 1.02	6.62 ± 0.42	14.8 ± 1.82	8.28 ± 0.35	0.858 ± 0.02	38.0 ± 7.79	0.445 ± 0.04	2.42 ± 0.95	2.84 ± 0.15
Brand C	55.6 ± 0.21	2.85 ± 0.13	1108 ± 14	16.9 ± 0.74	4.53 ± 0.18	20.1 ± 20.1	9.09 ± 0.47	0.853 ± 0.02	48.7 ± 0.16	0.650 ± 0.03	5.02 ± 2.17	2.66 ± 0.05
Brand D	50.5 ± 0.12	4.23 ± 0.16	1264 ± 31	12.6 ± 0.65	8.04 ± 0.98	24.7 ± 24.7	7.72 ± 0.25	0.348 ± 0.00	52.8 ± 0.99	0.625 ± 0.02	2.20 ± 0.66	2.23 ± 0.32
Brand N	66.1 ± 1.15	1.77 ± 0.05	790 ± 65	16.2 ± 0.28	3.76 ± 0.76	12.2 ± 12.2	5.76 ± 0.01	0.565 ± 0.01	42.9 ± 0.48	0.360 ± 0.01	3.46 ± 1.78	2.11 ± 0.01

(*continued on next page*)

Table 3 (*continued*)

Product Brand	Moisture (g/100 g)	Ash (g/ 100 g)	Energy (Calculated) (kJ/100 g)	Protein (g/100 g)	Carbohydrates (Calculated) (g/100 g)	Total Fat (g/100 g)	Saturated Fat (g/100 g)	Trans Fat (g/100 g)	Cholesterol (mg/100 g)	Sodium (g/100 g)	Iron (mg/ 100 g)	Zinc (mg/100 g)
Mean±SD	**58.4[e] ± 6.34**	**2.69 ± 1.05**	**1020[a]± 196**	**15.2[ab] ± 1.85**	**5.74 ± 1.88**	**17.9[a]± 5.31**	**7.71[a] ± 1.34**	**0.656[a]± 0.23**	**45.6[a] ± 6.72**	**0.520[c]± 0.13**	**3.28[ab] ± 1.65**	**2.46[a]± 0.35**
French polony												
Brand D	66.9 ± 0.21	2.85 ± 0.24	756 ± 22	12.5 ± 0.14	5.71 ± 0.14	12.1 ± 0.73	4.10 ± 0.14	< 0.1	25.0	1.05 ± 0.00	1.60 ± 0.00	0.635 ± 0.04
Brand E	73.1 ± 0.15	2.72 ± 0.18	498 ± 11	14.4 ± 0.14	5.45 ± 0.08	4.35 ± 0.27	1.35 ± 0.07	< 0.1	13.0	0.959 ± 0.03	1.80 ± 0.00	0.635 ± 0.02
Brand F	70.7 ± 0.08	3.33 ± 0.04	617 ± 10	11.4 ± 0.25	5.85 ± 0.64	8.78 ± 0.44	2.80 ± 0.00	< 0.1	39.0	1.04 ± 0.00	1.55 ± 0.07	0.880 ± 0.03
Brand J	69.0 ± 0.40	3.04 ± 0.07	664 ± 5	10.4 ± 1.36	8.08 ± 0.23	9.45 ± 0.66	3.10 ± 0.00	< 0.1	30.0	1.09 ± 0.01	1.75 ± 0.07	0.770 ± 0.08
Brand P	68.1 ± 0.18	2.970.03 ±	709 ± 0	10.9 ± 0.14	7.15 ± 0.12	10.9 ± 0.11	3.35 ± 0.07	< 0.1	36.0	0.931 ± 0.03	1.85 ± 0.07	0.960 ± 0.06
Mean±SD	**69.6[b] ± 2.29**	**2.98 ± 0.28**	**649[b]± 94**	**11.9[cde] ± 1.57**	**6.45 ± 1.08**	**9.11[b]± 2.80**	**2.94[bc] ± 0.95**	**< 0.1**	**28.6[c] ± 10.26**	**1.02[b]± 0.06**	**1.71[c] ± 0.13**	**0.776[b]± 0.14**
Chicken polony												
Brand D	71.7 ± 0.16	2.97 ± 0.03	576 ± 1	13.6 ± 0.28	4.46 ± 0.56	7.28 ± 0.11	2.25 ± 0.07	< 0.1	26.0	1.13 ± 0.00	1.40 ± 0.00	0.625 ± 0.02
Brand E	66.4 ± 0.13	3.29 ± 0.04	732 ± 14	13.1 ± 0.35	6.45 ± 0.04	10.8 ± 0.00	2.65 ± 0.07	< 0.1	20.0	1.14 ± 0.02	0.750 ± 0.06	0.510 ± 0.03
Brand F	65.1 ± 0.18	3.05 ± 0.11	816 ± 1	11.4 ± 0.07	6.85 ± 0.03	13.7 ± 0.14	4.30 ± 0.00	< 0.1	44.0	0.950 ± 0.03	1.75 ± 0.21	0.990 ± 0.01
Brand H	61.7 ± 0.75	2.55 ± 0.04	953 ± 9	11.4 ± 3.18	7.13 ± 2.18	17.3 ± 0.14	4.75 ± 0.07	< 0.1	33.0	0.881 ± 0.00	0.460 ± 0.01	0.325 ± 0.01
Brand J	66.1 ± 0.35	2.89 ± 0.17	739 ± 3	9.75 ± 0.86	10.7 ± 0.68	10.6 ± 0.00	3.30 ± 0.014	< 0.1	35.0	0.978 ± 0.01	2.10 ± 0.42	0.865 ± 0.06
Brand P	68.2 ± 0.01	2.82 ± 0.20	738 ± 7	10.0 ± 0.04	6.78 ± 0.01	12.2 ± 0.00	3.80 ± 0.00	< 0.1	38.0	0.984 ± 0.01	1.85 ± 0.07	0.910 ± 0.04
Mean±SD	**66.5[bc] ± 3.17**	**2.93 ± 0.25**	**759[b]± 118**	**11.5[de] ± 1.79**	**7.05 ± 2.05**	**12.0[b]± 3.20**	**3.51[b] ± 0.92**	**< 0.1**	**32.7[abc] ± 8.57**	**1.01[b]± 0.10**	**1.39[c] ± 0.64**	**0.704[b]± 0.25**
Red viennas												
Brand D	66.5 ± 0.26	2.82 ± 0.01	749 ± 17	13.3 ± 1.48	5.97 ± 1.86	11.4 ± 0.64	4.05 ± 0.21	< 0.1	24.0	1.07 ± 0.05	1.75 ± 0.07	0.880 ± 0.03
Brand E	66.3 ± 0.07	3.57 ± 0.04	653 ± 1	15.9 ± 0.21	7.36 ± 0.19	6.97 ± 0.01	2.25 ± 0.07	< 0.1	29.0	1.15 ± 0.02	2.30 ± 0.00	0.885 ± 0.04
Brand F	64.6 ± 0.17	3.68 ± 0.03	763 ± 10	12.2 ± 0.85	8.33 ± 0.09	11.2 ± 0.62	3.35 ± 0.49	< 0.1	33.0	1.05 ± 0.04	2.10 ± 0.00	1.30 ± 0.00
Brand J	56.7 ± 0.08	3.15 ± 0.00	1103 ± 20	13.1 ± 0.42	6.10 ± 1.56	21.0 ± 1.06	7.90 ± 0.28	< 0.1	43.0	1.04 ± 0.01	0.790 ± 0.20	0.770 ± 0.01
Brand P	65.5 ± 0.23	3.58 ± 0.03	668 ± 5	12.1 ± 0.00	11.7 ± 0.11	7.13 ± 0.09	2.25 ± 0.07	< 0.1	34.0	0.944 ± 0.02	1.80 ± 0.00	0.870 ± 0.04
Mean±SD	**63.9[cd] ± 3.89**	**3.36 ± 0.34**	**787[b]± 173**	**13.3[bcd] ± 1.55**	**7.88 ± 2.34**	**11.5[b]± 5.39**	**3.96[b]± 2.21**	**< 0.1**	**32.6[abc] ± 7.02**	**1.05[b]± 0.07**	**1.75[c]± 0.55**	**0.941[b]± 0.20**
Chicken viennas												
Brand D	68.1 ± 1.36	3.36 ± 0.09	686 ± 20	13.3 ± 0.28	5.13 ± 1.99	10.1 ± 0.25	3.15 ± 0.07	< 0.1	39.0	1.15 ± 0.00	0.645 ± 0.22	0.365 ± 0.26
Brand E	68.2 ± 0.61	3.10 ± 0.07	671 ± 6	14.5 ± 0.14	5.03 ± 1.07	9.16 ± 0.25	2.90 ± 0.00	< 0.1	40.0	0.988 ± 0.01	0.920 ± 0.07	0.620 ± 0.06
Brand F	67.4 ± 0.04	3.33 ± 0.02	656 ± 2	12.0 ± 0.14	9.27 ± 0.13	7.97 ± 0.04	2.50 ± 0.00	< 0.1	40.0	0.964 ± 0.01	2.05 ± 0.07	0.920 ± 0.03
Brand J	70.1 ± 0.09	2.89 ± 0.16	675 ± 4	12.4 ± 1.20	3.83 ± 1.29	10.8 ± 0.16	3.40 ± 0.00	< 0.1	48.0	0.980 ± 0.02	0.870 ± 0.10	0.790 ± 0.01

(*continued on next page*)

Table 3 (*continued*)

Product Brand	Moisture (g/100 g)	Ash (g/100 g)	Energy (Calculated) (kJ/100 g)	Protein (g/100 g)	Carbohydrates (Calculated) (g/100 g)	Total Fat (g/100 g)	Saturated Fat (g/100 g)	Trans Fat (g/100 g)	Cholesterol (mg/100 g)	Sodium (g/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Brand M	67.2 ± 0.06	3.21 ± 0.18	649 ± 1	15.5 ± 0.28	6.80 ± 0.10	7.30 ± 0.06	2.25 ± 0.07	< 0.1	34.0	1.11 ± 0.02	2.65 ± 0.35	1.04 ± 0.09
Brand P	62.6 ± 0.18	3.57 ± 0.04	732 ± 6	12.2 ± 0.28	13.8 ± 0.15	7.86 ± 0.09	2.40 ± 0.00	< 0.1	33.0	0.984 ± 0.05	1.70 ± 0.14	0.925 ± 0.08
Mean±SD	**67.3^{bc} ± 2.43**	**3.24 ± 0.24**	**678^{b}± 29**	**13.3^{de}± 1.41**	**7.31 ± 3.60**	**8.86^{bc}± 1.33**	**2.79^{bc}± 0.45**	**< 0.1**	**39.0^{abc} ± 5.37**	**1.03^{b}± 0.08**	**1.47^{c}± 0.77**	**0.776^{b}± 0.25**
p-value	< 0.001	0.01	< 0.001	< 0.001	0.011	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Footnote: Values with different superscripts in a column differ significantly

Cholesterol values for French polony, chicken polony, red viennas and chicken viennas, were only received as single values from the outsourced, subcontracted laboratory.

from 9.89 g/100 g in the tinned meatballs to 45.4 g/100 g and 45.6 g/100 g in the frozen products (hamburger patties and sausages). This is lower than the cholesterol values reported for raw and cooked beef and chicken (Table 4). The difference in cholesterol levels between processed meats and red meats primarily stems from their preparation and composition which alters the fat content (lower animal-derived fat in processed meat) and overall nutritional profile.

3.1.4. Minerals - iron, zinc and sodium

Iron serves various functions within the human body, aiding in the storage and utilisation of oxygen in muscles, contributing to the functionality of proteins, and enzymes and supporting metabolic processes. Iron deficiency is one of the most recognised nutritional deficiencies, impacting particularly children, premenopausal women and people in low-income and middle-income countries (Pasricha et al., 2021). This deficiency arises from an imbalance between iron needs, absorption and losses within the body. Dietary iron exists in two primary forms: haem and non-haem. Haem iron, found more abundantly in animal-derived foods is more readily absorbed by the body, while plant-based and iron-fortified foods primarily contain non-haem iron. Enhancing factors such as ascorbic acid and meat/fish/poultry may increase non-haem iron bioavailability fourfold (Monsen, 1988). Therefore, the consumption of animal-derived products is often recommended for individuals at risk of iron deficiency, however observational studies reported that a high intake of haem iron may increase the risk of colon cancer (FAO, 2023; World Health Organization, 2015).

This analysis focused on the total iron content in the eight food products sampled. The total iron content ranged from 1.39 mg/100 g in chicken polony to 3.61 mg/100 g in corned beef making it a valuable source of iron for those who have limited access to unprocessed meat. More research is needed on the distribution of haem and non-haem iron in processed meat products. The iron content in the frozen products is higher than in raw beef, while the cooked beef has a higher iron content than the RTE products. Chicken (raw and boiled) has a lower iron content than the processed meat products.

Zinc is necessary to all biological systems and plays a role in various vital functions at cellular and subcellular levels, protein metabolism, cell growth and immunity. Well-documented outcomes of zinc deficiency include impaired physical growth, weakened immune responses, and compromised reproductive and neurological systems. The consequences are associated with stunting, increased child morbidity and mortality, and adverse maternal health and pregnancy outcomes (Gupta et al., 2020). A daily adequate intake is essential as the body has no specialised storage system for zinc. A considerable number of individuals in low- and middle-income countries (LMICs) experience insufficient zinc intake due to restricted access to zinc-rich foods like animal products. This situation highlights zinc deficiency as a prevalent public health concern across nearly all LMICs. Dietary zinc of the processed meat products evaluated in this study ranged from 0.70 and 0.78 mg/100 g in the chicken polony, chicken vienna and French polony, respectively to a significantly higher zinc content of 2.86 mg/100 g in hamburger patties. In comparison, cooked beef has nearly double the zinc content. However, processed meats, particularly products with a higher red meat content, such as hamburger patties and beef sausages can still be a valuable source of bioavailable zinc.

Although sodium is essential in the diet and plays vital roles in regulating blood pressure, water transport into and out of cells, tissue osmolality and transmission of nerve cell impulses, the excessive intake of sodium has become a global health risk (Farquhar et al., 2015; Tremblay et al., 2024). Excessive intake of sodium has been linked to hypertension and an increase in chronic diseases. It is recommended that adults consume less than 2 300 mg of sodium per day (World Health Organization, 2024). Many countries have adopted sodium (Na) targets for food reformulation, with 19 countries already having mandatory maximum Na limits for foods (Santos et al., 2021).

South Africa was one of the first countries to adopt such an approach

Table 4
Comparison of nutrient data of the eight analysed processed meat products with raw and cooked beef and raw and cooked chicken with skin.

Product Brand	Moisture (g/100 g)	Ash (g/100 g)	Energy (Calculated) (kJ/100 g)	Protein (g/100 g)	Carbohydrates (Calculated)(g/100 g)	Total Fat(g/100 g)	Saturated Fat(g/100 g)	Trans Fat(g/100 g)	Cholesterol (mg/100 g)	Sodium (g/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Ready-to-eat processed meat products in comparison with cooked beef and chicken												
Tinned corned beef	66.9	2.95	741	11.4	7.26	11.5	5.67	0.388	28.6	1.28	3.61	2.26
Tinned meatballs	76.0	2.08	447	8.31	9.95	3.69	1.68	0.112	9.89	0.543	1.86	1.2
French polony	69.6	2.98	649	11.9	6.45	9.11	2.94	< 0.1	28.6	1.02	1.71	0.776
Chicken polony	66.5	2.93	759	11.5	7.05	12.0	3.51	< 0.1	32.7	1.01	1.39	0.704
Red viennas	63.9	3.36	787	13.3	7.88	11.5	3.96	< 0.1	32.6	1.05	1.75	0.941
Chicken viennas	67.3	3.24	678	13.3	7.31	8.86	2.79	< 0.1	39.0	1.03	1.47	0.776
#Beef, C-age, cooked	50.3	2.8	1189	27.3	-	19.6	9.11	-	82	0.09	2.8	4.9
++Chicken, meat and skin, boiled	59.6	1.0	923	26.8	-	12.6	3.52	-	86	0.056	0.8	1.78
Frozen processed meat products in comparison with raw beef and chicken												
Hamburger patties	60.7	2.25	987	15.9	3.31	17.9	6.35	0.553	45.4	0.363	3.16	2.86
Frozen beef sausages	58.4	2.69	1020	15.2	5.74	17.9	7.71	0.656	45.6	0.520	3.28	2.46
#Beef, C-age, raw	60.7	0.8	1057	18.4	-	20.1	9.19	-	61	0.10	1.9	3.53
++Chicken, meat and skin, raw	68.6	0.9	778	20.1	-	11.8	3.23	-	63	0.049	1.6	1.11

++(SAFOODS, 2017)
(Schönfeldt & Welgemoed, 1996; Hall et al., 2015, 2016; SAFOODS, 2017)

through its government-enforced regulation R.214 (South African National Department of Health, 2013, 2019). This regulation aimed to decrease nationwide Na intake by a predicted 850 mg/day and thereby reduce annual cardiovascular deaths (CVD) by 11 % (Bertram et al., 2012). Consumption of processed meats was reported to be the second largest contributor to total dietary sodium intake in South Africa (Charlton et al., 2005). Therefore, the Department of Health included certain categories of processed meat products under regulation R214. The sodium content of the eight products analysed in this study ranged from 0.363 g/100 g in the frozen hamburger patties to > 1 g/100 g in the polonies and viennas. The corned beef has on average 1.28 g sodium/100 g with a large variation between samples (min =

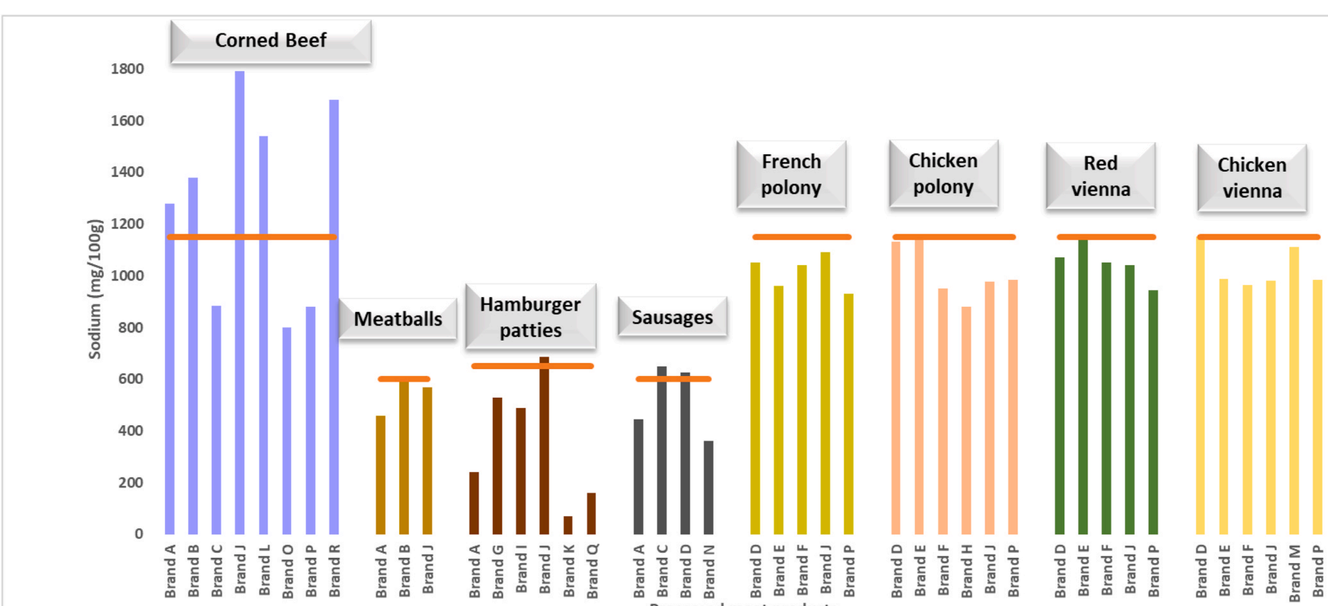

Fig. 1. Average sodium content (mg/100 g) analysed compared to the sodium reduction regulation (R.214) final targets indicated by the horizontal lines. (The horizontal bar represents the Maximum Total Sodium per 100 g foodstuff as stipulated by the regulations relating to the reduction of sodium in certain foodstuffs, R.214) (South African National Department of Health, 2013, 2019).

0.80 g/100 g, max = 1.79 g/100 g). As can be seen in Fig. 1 only 38 % of corned beef and 50 % of the frozen beef sausages complied with the sodium reduction regulations (R.214). Whereas, seven of the eight brands of frozen hamburger patties and all the tinned meatballs, French polony, chicken polony, red and chicken viennas complied with the regulations. This finding corresponds to studies done between February 2019 and September 2020 by van der Westhuizen et al. (2023) and Charlton et al. (2024). Implementing mandatory sodium reduction targets for food reformulation, as outlined in Regulation R.214 in South Africa, has successfully reduced the sodium content in most processed meat products. This reformulation will likely contribute to a diminished impact of these products on overall dietary sodium intake within the population (Charlton et al., 2021; Strauss-Kruger et al., 2023). Despite significant reductions in sodium levels due to regulatory measures, improving monitoring and evaluation is essential to maximise health benefits and ensure compliance by all meat processors. Specific food inspectors need to be appointed and equipped to enforce regulations at a national level, covering both formal and informal industries. Consolidating instances of non-compliance and prosecuting them as company-wide violations, rather than isolated incidents, will reduce administrative hurdles and allow for meaningful penalties. Additionally, restructuring penalties will create stronger disincentives for non-compliance, ensuring better adherence to regulations (van der Westhuizen et al., 2023; Webster et al., 2022).The launch of the National Strategic Plan for Non-Communicable Disease (NCD) Prevention and Management (2022–2027) in July 2022 by the South African National Department of Health may encourage increased attention to monitoring population sodium intake and implementing consumer education strategies to reduce discretionary sodium consumption.

3.2. Evaluation of the nutrient density of processed meat products

For maximum effectiveness nutrient profile models need to be transparent, based on publicly accessible nutrient composition data and validated against independent measures of a healthy diet. Choosing the best nutrient profile model from among multiple alternatives proved to be a scientific challenge further constrained by analytical cost and competency in a developing country context.

Foods that supply relatively more nutrients than energy (kiloJoules) are defined as nutrient-dense. Table 5 reports on the Nutrient Rich Foods (NRF9.3) Index values and costs for the selected food items. The NRF9.3 score for the processed food products ranged from 16 to 104 with the tinned meatballs having the highest nutrient density score. The NRF Index calculations were limited to nine selected macronutrients, vitamins, and minerals. If different nutrients are used, the results may vary. Tinned meatballs and French polony have the best nutritional value per cost comparable to that of beef and chicken, while red and chicken viennas and tinned corned meat have the lowest nutrient-to-price ratio (NPR).

Fig. 2 shows the relation of NPR (per 100 kcal) and the nutrient density score (NRF9.3) for the selected processed foods compared to raw beef and chicken. The tinned meatballs in gravy and the raw beef meat have a relatively higher nutrient density score but also have a higher nutritional value per cost of all the products in the study. For the ready-to-eat products, most of the factors such as logistics, processing and preparation are already included in the price. For the raw products, preparation costs (eg. electricity), cooking loss, and edible portion still need to be accounted for. A study done in Cape Town between 2020 and 2021 showed that processed meats such as polonies, viennas and sausages are cheaper animal-source foods, but their nutrient density is also lower in comparison with red meat, chicken and organ meats (Madlala et al., 2023). In Africa, meat is associated with socioeconomic status and is an important part of culture and socialisation (Kroll, 2016; Mensah et al., 2022; Puoane et al., 2006). People therefore try to consume it on a daily basis, although the increased cost of living in urban environments forces many to consume cheaper alternatives.

Table 5
Nutrient-Rich Foods (NRF9.3) Index values and food costs calculated per 100 g for the selected processed foods compared to other sources of protein.

Processed meat product	Energy Density (kcal/ 100 g)	ZAR/ 100 g	ZAR/ 100 kcal	Nutrient density (NRF9.3/ 100 kcal)	*NPR (NRF9.3/ ZAR 100 kcal)
Corned meat	177	11.78	6.65	32	4.76
Tinned meatballs in gravy	107	7.50	7.01	104	14.78
Beef hamburger patties	236	13.85	5.86	58	9.92
Frozen beef sausages	244	12.15	4.98	41	8.16
French polony	155	5.14	3.31	35	10.49
Chicken polony	181	5.86	3.23	27	8.40
Red viennas	188	7.12	3.78	17	4.47
Chicken viennas	162	8.82	5.44	22	4.05
Beef, C-age, raw carcass	284	10.64	4.21	65	15.44
Chicken, meat and skin, raw	221	7.00	3.17	42	13.15

* NPR = Nutrient-to-price-ratio

The idea of healthy food often centres around the lack of saturated fat, added sugars and sodium, rather than the presence of beneficial nutrients. In a study to explore the role of lifestyle and socioeconomic factors on the impact of processed foods, it was found that the adverse effect of processed food intake on the physical health of the participants was not observed in those with healthy lifestyles and higher socioeconomic status (Hosseinpour-Niazi et al., 2024). Economic factors can be a barrier to the adoption of healthier diets, thereby reducing the effectiveness of dietary guidance (Monsivais & Drewnowski, 2007). Research should focus on food patterns and overall diet quality, especially concerning sustainability and cost. Incorporating the concept of nutrient density into healthier everyday diets necessitates combining nutrient profiling methods with other strategies to improve food habits and health. Health promotion strategies may need to be complemented with environmental and policy measures to ensure equitable access to affordable, nutrient-dense foods.

4. Limitations of the study

The sampling plan followed focussed on middle- and low-income consumers and excluded more expensive and specialised products, such as bacon and salami. Samples were only procured from the big retailers in South Africa, not including small enterprises and products available in rural areas. Vitamin values for these products were not analysed and food matching was used to derive values for these nutrients to calculate the NRF9.3 scores for each product. This again highlights the need for country-specific food composition data. Nutrient data for cooked beef and chicken meat was not readily available and in Table 4, all products were compared to the raw meat samples only. Choosing the best nutrient profile model from multiple alternatives proved to be a scientific challenge further constrained by analytical cost and competency in a developing country context.

5. Conclusion

Processed meats in South Africa provide varying levels of essential nutrients such as protein, iron, and zinc, with differences in nutrient density and nutrient-to-price ratios depending on the product type.

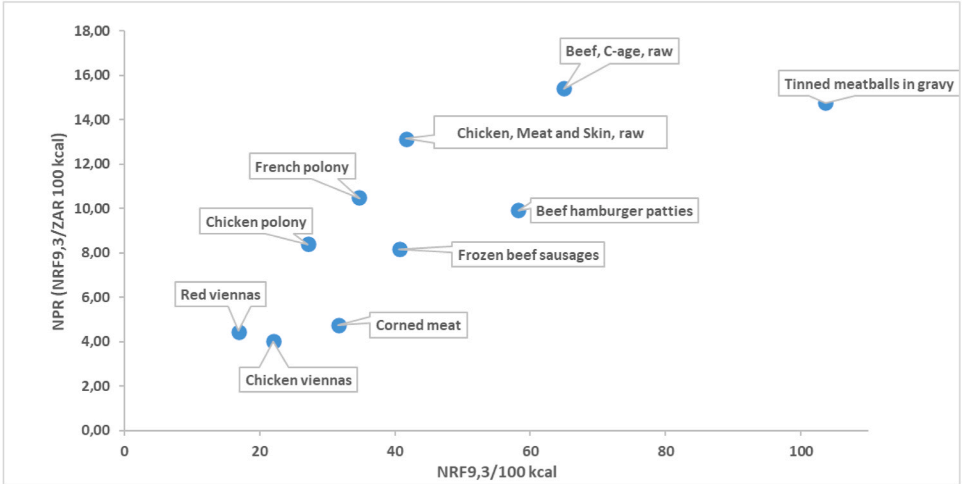

Fig. 2. Nutrient Rich Foods (NRF9.3) scores shown in relation to the nutrient-to-price ratio (NPR) (NRF9.3/price 100 kcal) for the selected processed meat products and raw beef and chicken.

Despite their potential nutritional contributions, processed meats are generally lower in protein and higher in fat and sodium than unprocessed beef and chicken meat, highlighting the need for consumer education on healthier processed meat choices and the benefits of moderating their consumption.

Limited data exist on the quantity (amount, portion size, frequency) of processed meat is consumed by different socio-economic groups within South Africa. Such data is important to identify vulnerable populations, tailor health-promoting campaigns and inform policies and regulations. In will be insightful to analyse additional products and as the food processing and policy landscape in South Africa develop, also to re-analyse the current products to ascertain the food industry's adherence to regulations. Additionally, there is no current review of the relative cost or value per unit of nutrient of processed meat products compared with other processed products deemed high in protein, such as plant-based meat alternatives and tinned beans, peas, lentils and soya.

CRediT authorship contribution statement

Beulah Pretorius: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Carmen Muller:** Writing – review & editing, Investigation. **Hettie C. Schönfeldt:** Writing – review & editing, Resources, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors wish to thank our colleague at Stas4Science, Ms Marie Smit, for assistance with the statistical analyses. The authors acknowledge the funding from the Department of Science and Innovation (DSI)/ National Research Foundation (NRF) South African Research Chairs Initiative (SARChl) in the National Development Plan Priority Area of Nutrition and Food Security (Unique number: SARCI170808259212) and Red Meat Research and Development South Africa (RMRDSA). The grant holders acknowledge that opinions, findings, and conclusions or recommendations expressed in any publication generated by the NRF-supported research are that of the author(s) and that the NRF accepts no liability whatsoever in this regard.

Data availability

Data will be made available on request.

References

FAO, IFAD, UNICEF, WFP, & WHO. (2024). The State of Food Security and Nutrition in the World 2024. FAO; IFAD; UNICEF; WFP; WHO; https://doi.org/10.4060/cd1254en.

AOAC. (1996). Official method 976.26 (16th ed.). Association of Official Analytical Chemists.

AOAC. (2000). Official method 996.06 (17th ed.). Association of Official Analytical Chemists.

AOAC. (2005). Official Method 942.05 (18th ed.). Association of Official Analytical Chemists.

AOAC. (2007). Official Method 984.27 (18th ed.). Association of Official Analytical Chemists.

Astrup, A., Magkos, F., Bier, D.M., Brenna, J.T., de Oliveira Otto, M.C., Hill, J.O., King, J. C., Mente, A., Ordovas, J.M., Volek, J.S., Yusuf, S., Krauss, R.M., 2020. Saturated fats and health: a reassessment and proposal for food-based recommendations: JACC state-of-the-art review. J. Am. Coll. Cardiol. 76 (7), 844–857. https://doi.org/10.1016/j.jacc.2020.05.077.

Bertram, M.Y., Steyn, K., Wentzel-Viljoen, E., Tollman, S., Hofman, K.J., 2012. Reducing the sodium content of high-salt foods: effect on cardiovascular disease in South Africa. South Afr. Med. J. 102 (9), 743–745. https://doi.org/10.7196/SAMJ.5832.

CDC (Centers for Disease Control and Prevention). (2024). LDL and HDL Cholesterol and Triglycerides. ⟨https://www.cdc.gov/cholesterol/about/ldl-and-hdl-cholesterol-and-triglycerides.html⟩. Accessed January 17, 2025.

Charlton, K.E., Corso, B., Ware, L., Schutte, A.E., Wepener, L., Minicuci, N., Naidoo, N., Kowal, P., 2021. Effect of South Africa's interim mandatory salt reduction programme on urinary sodium excretion and blood pressure. Prev. Med. Rep. 23, 101469. https://doi.org/10.1016/j.pmedr.2021.101469.

Charlton, K., Pretorius, B., Shakhane, R., Naidoo, P., Cimring, H., Hussain, K., Nojilana, B., Webster, J., 2024. Journal of Food Composition and Analysis Compliance of the food industry with mandated salt target levels in South Africa: towards development of a monitoring and surveillance framework. J. Food Compos. Anal. 126 (December 2023), 105908. https://doi.org/10.1016/j.jfca.2023.105908.

Charlton, K., Steyn, K., Levitt, N.S., Zulu, J.V., Jonathan, D., Veldman, F.J., Nel, J., 2005. Diet and blood pressure in South Africa: Intake of foods containing sodium, potassium, calcium, and magnesium in three ethnic groups. Nutrition 21 (1), 39–50. https://doi.org/10.1016/j.nut.2004.09.007.

Codex Allimentarius. (2021). CXG 2-1985 - Guidelines on nutrition labelling. ⟨https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk= 1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B2-1985%252FCXG_002e.pdf⟩. Accessed January 16, 2025.

Drewnowski, A., Dwyer, J., King, J.C., Weaver, C.M., 2019. A proposed nutrient density score that includes food groups and nutrients to better align with dietary guidance. Nutr. Rev. 77 (6), 404–416. https://doi.org/10.1093/nutrit/nuz002.

European Food Safety Authority (EFSA), 2015. The food classification and description system FoodEx 2 (revision 2). EFSA Support. Publ. 12 (5), 1–90. https://doi.org/10.2903/sp.efsa.2015.en-804.

FAO. (2011). INFOODS Guidelines for food matching. ⟨https://www.fao.org/fileadmin/templates/food_composition/documents/upload/INFOODSGuidelinesforFoodMatching_final_july2011.pdf⟩. Accessed January 16, 2025.

FAO. (2013). Dietary protein quality evaluation in human nutrition. Report of an FAO Expert Consultation. In FAO food and nutrition paper (Vol. 92). Food and Agriculture Organization of the United Nations.
FAO. (2023). Contribution of terrestrial animal source food to healthy diets for improved nutrition and health outcomes. https://doi.org/https://doi.org/10.4060/cc3912en.
Farquhar, W.B., Edwards, D.G., Jurkovitz, C.T., Weintraub, W.S., 2015. Dietary sodium and health. J. Am. Coll. Cardiol. 65 (10), 1042–1050. https://doi.org/10.1016/j.jacc.2014.12.039.
Fulgoni, V.L., Keast, D.R., Drewnowski, A., 2009. Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. J. Nutr. 139 (8), 1549–1554. https://doi.org/10.3945/jn.108.101360.
Godbharle, S., Kesa, H., Jeyakumar, A., Shambharkar, P., 2024. Socio-demographic and economic factors associated with the consumption of processed foods in South Africa – evidence from Demographic and Health Survey VII. Public Health 226, 190–198. https://doi.org/10.1016/j.puhe.2023.11.018.
Greenfield, H., Southgate, D.A.T., 2003. Food Composition Data: production, management and use. FAO.
Gupta, S., Brazier, A.K.M., Lowe, N.M., 2020. Zinc deficiency in low- and middle-income countries: prevalence and approaches for mitigation. J. Hum. Nutr. Diet. 33 (5), 624–643. https://doi.org/10.1111/jhn.12791.
Hall, N., Schönfeldt, H.C., Pretorius, B., 2015. Changes in the composition of South African red meat. South Afr. J. Anim. Sci. 45 (3). https://doi.org/10.4314/sajas.v45i3.10.
Hall, N., Schönfeldt, H.C., Pretorius, B., 2016. Fatty acids in beef from grain- and grass-fed cattle: The unique South African scenario. South Afr. J. Clin. Nutr. 29 (2).
Heileson, J.L., 2020. Dietary saturated fat and heart disease: a narrative review. In: Nutrition Reviews, 78. Oxford University Press, pp. 474–485. https://doi.org/10.1093/nutrit/nuz091.
Holmes, M.D., Dalal, S., Sewram, V., Diamond, M.B., Adebamowo, S.N., Ajayi, I.O., Adebamowo, C., Chiwanga, F.S., Njelekela, M., Laurence, C., Volmink, J., Bajunirwe, F., Nankya-Mutyoba, J., Guwatudde, D., Reid, T.G., Willett, W.C., Adami, H.O., Fung, T.T., 2018. Consumption of processed food dietary patterns in four African populations. Public Health Nutr. 21 (8), 1529–1537. https://doi.org/10.1017/S136898001700386X.
Hosseinpour-Niazi, S., Niknam, M., Amiri, P., Mirmiran, P., Ainy, E., Izadi, N., Gaeini, Z., Azizi, F., 2024. The association between ultra-processed food consumption and health-related quality of life differs across lifestyle and socioeconomic strata. BMC Public Health 24 (1), 1955. https://doi.org/10.1186/s12889-024-19351-7.
Kroll, F. (2016). Foodways of the poor in South Africa (Issue 36). ⟨https://uwcscholar.uwc.ac.za/bitstream/handle/10566/4518/wp_36_foodways_of_the_poor_in_south_africa_2016.pdf?sequence= 1&isAllowed=y⟩. Accessed January 16, 2025.
Labadarios, D., Steyn, N., Maunder, E., MacIntryre, U., Gericke, G., Swart, R., Huskisson, J., Dannhauser, A., Vorster, H., Nesmvuni, A., Nel, J., 2005. The National Food Consumption Survey (NFCS): South Africa, 1999. Public Health Nutr. 8 (5), 533–543. https://doi.org/10.1079/phn2005816.
Lewis, J. (2019). Codex nutrient reference values. ⟨https://www.fao.org/3/ca6969en/CA6969EN.pdf⟩. Acceessed January 16, 2025.
Madlala, S.S., Hill, J., Kunneke, E., Faber, M., 2023. Nutrient density and cost of commonly consumed foods: A South African perspective. J. Nutr. Sci. 12 (12), 1–13. https://doi.org/10.1017/jns.2022.119.
Mensah, D.O., Mintah, F.O., Oteng, S.A., Lillywhite, R., Oyebode, O., 2022. We're meat, so we need to eat meat to be who we are': Understanding motivations that increase or reduce meat consumption among emerging adults in the University of Ghana food environment. Meat Sci. 193. https://doi.org/10.1016/j.meatsci.2022.108927.
Michel, M., Eldridge, A.L., Hartmann, C., Klassen, P., Ingram, J., Meijer, G.W., 2024. Benefits and challenges of food processing in the context of food systems, value chains and sustainable development goals. Trends Food Sci. Technol., 104703 https://doi.org/10.1016/j.tifs.2024.104703.
Miller, V., Reedy, J., Cudhea, F., Zhang, J., Shi, P., Erndt-Marino, J., Coates, J., Micha, R., Webb, P., Mozaffarian, D., Abbott, P., Abdollahi, M., Abedi, P., Abumweis, S., Adair, L., Al Nsour, M., Al-Daghri, N., Al-Hamad, N., Al-Hooti, S., Zohoori, F.V., 2022. Global, regional, and national consumption of animal-source foods between 1990 and 2018: findings from the Global Dietary Database. Lancet Planet. Health 6 (3), e243–e256. https://doi.org/10.1016/S2542-5196(21)00352-1.
Monsen, E.R., 1988. Iron nutrition and absorption: dietary factors which impact iron bioavailability. J. Am. Diet. Assoc. 88 (7), 786–790.
Monsivais, P., Drewnowski, A., 2007. The rising cost of low-energy-density foods. J. Am. Diet. Assoc. 107 (12), 2071–2076. https://doi.org/10.1016/j.jada.2007.09.009.
Monteiro, C.A., 2009. Nutrition and health. The issue is not food, nor nutrients, so much as processing. Public Health Nutr. 12 (5), 729–731. https://doi.org/10.1017/S1368980009005291.
NEVO. (2023). Dutch Food Composition Database (NEVO). Online Version 2023/8.0. ⟨https://www.rivm.nl/en/dutch-food-composition-database⟩. Accessed January 16, 2025.
Nunes, E.A., Colenso-Semple, L., McKellar, S.R., Yau, T., Ali, M.U., Fitzpatrick-Lewis, D., Sherifali, D., Gaudichon, C., Tomé, D., Atherton, P.J., Robles, M.C., Naranjo-Modad, S., Braun, M., Landi, F., Phillips, S.M., 2022. Systematic review and meta-analysis of protein intake to support muscle mass and function in healthy adults. In: Journal of Cachexia, Sarcopenia and Muscle, 13. John Wiley and Sons Inc, pp. 795–810. https://doi.org/10.1002/jcsm.12922.
Pasricha, S.R., Tye-Din, J., Muckenthaler, M.U., Swinkels, D.W., 2021. Iron deficiency. Lancet 397 (10270), 233–248. https://doi.org/10.1016/S0140-6736(20)32594-0.
Payne, R.W., Murry, D.A., Harding, S.A., Baird, D.B., Soutar, D.M., 2009. GenStat for Windows introduction. VSN International.
Poitevin, E., 2012. Determination of calcium, copper, iron, magnesium, manganese, potassium, phosphorus, sodium, and zinc in fortified food products by microwave digestion and inductively coupled plasma-optical emission spectrometry: single-laboratory validation and ring tri. J. AOAC Int. 95 (1), 177–185. https://doi.org/10.5740/jaoacint.CS2011_14.
Popkin, B.M., Corvalan, C., Grummer-Strawn, L.M., 2020. Dynamics of the double burden of malnutrition and the changing nutrition reality. Lancet 395 (10217), 65–74. https://doi.org/10.1016/S0140-6736(19)32497-3.
Public Health England. (2021). McCance and Widdowson's composition of foods integrated dataset. Composition of Foods Integrated Dataset (CoFID). ⟨https://assets.publishing.service.gov.uk/media/60538b91e90e07527df82ae4/McCance_Widdowsons_Composition_of_Foods_Integrated_Dataset_2021.xlsx⟩. Accessed January 16, 2025.
Puoane, T., Matwa, P., Hughes, G., Bradley, Hazel A., 2006. Socio-cultural factors influencing food consumption patterns in the black African population in an urban township in South Africa. Hum. Ecol. Spec. , 14, 89–93. ⟨https://www.researchgate.net/publication/228982491⟩.
Reardon, T., Tschirley, D., Liverpool-Tasie, L.S.O., Awokuse, T., Fanzo, J., Minten, B., Vos, R., Dolislager, M., Sauer, C., Dhar, R., Vargas, C., Lartey, A., Raza, A., Popkin, B. M., 2021. The processed food revolution in African food systems and the double burden of malnutrition. Glob. Food Secur. 28. https://doi.org/10.1016/j.gfs.2020.100466.
Ronquest-Ross, L.C., 2016. Food consumption changes in South Africa since 1994. Food Technol. 70 (8), 1–12.
SAFOODS, 2017. In: van Graan, A., Chetty, J., Jumat, M. (Eds.), SAMRC Food Composition Tables for South Africa, 5th ed.). South African Medical Research Council.
Santos, J.A., Tekle, D., Rosewarne, E., Flexner, N., Cobb, L., Al-Jawaldeh, A., Kim, W.J., Breda, J., Whiting, S., Campbell, N., Neal, B., Webster, J., Trieu, K., 2021. A systematic review of salt reduction initiatives around the world: a midterm evaluation of progress towards the 2025 global non-communicable diseases salt reduction target. Adv. Nutr. 12 (5), 1768–1780. https://doi.org/10.1093/advances/nmab008.
Schönfeldt, H.C., & Welgemoed, C. (1996). Composition of South African beef. South African Meat Board.
South African National Department of Health, 2011. Regulations relating to trans-fat in foodstuffs (R.127). In: Government Gazette, 34029, pp. 1–4.
South African National Department of Health, 2013. Regulations relating to the reduction of sodium in certain foodstuffs and related matters. Gov. Gaz. 583 (37230), 1–4. ⟨http://www.greengazette.co.za/pages/national-gazette-37230-of-17-january-2014-vol-583_20140117-GGN-37230-003⟩.
South African National Department of Health, 2019. Regulations relating to the reduction of sodium in certain foodstuffs and related matters: amendment. Gov. Gaz. 42496, 26–27. ⟨https://extranet.who.int/ncdccs/Data/ZAF_B25_s21_Sodium Reduction in Certain Foodstuffs Regs 812 of 31 May 2019.pdf⟩.
Strauss-Kruger, M., Wentzel-Viljoen, E., Ware, L.J., Van Zyl, T., Charlton, K., Ellis, S., Schutte, A.E., 2023. Early evidence for the effectiveness of South Africa's legislation on salt restriction in foods: the African-PREDICT study. J. Hum. Hypertens. 37 (1), 42–49. https://doi.org/10.1038/s41371-021-00653-x.
Tremblay, A., Gagné, M.P., Pérusse, L., Fortier, C., Provencher, V., Corcuff, R., Pomerleau, S., Foti, N., Drapeau, V., 2024. Sodium and human health: what can be done to improve sodium balance beyond food processing? Nutrients 16 (8). https://doi.org/10.3390/nu16081199.
USDA. (2022). USDA Food and Nutrient Database for Dietary Studies 2019-2020. ⟨http://www.ars.usda.gov/nea/bhnrc/fsrg⟩. Accessed October 23, 2024.
van der Westhuizen, B., Frank, T., Karim, S.A., Swart, E.C., 2023. Determining food industry compliance to mandatory sodium limits: successes and challenges from the South African experience. Public Health Nutr. https://doi.org/10.1017/S1368980023000757.
Vermeulen, H., Schönfeldt, H.C., Pretorius, B., 2015. A consumer perspective of the South African red meat classification system. South Afr. J. Anim. Sci. 45 (3). https://doi.org/10.4314/sajas.v45i3.11.
Vorster, H., Badham, J., Venter, C., 2013. Food-based dietary guidelines for South Africa. South Afr. J. Clin. Nutr. 26 (3), S1–S164.
Webster, J., Santos, J.A., Hogendorf, M., Trieu, K., Rosewarne, E., Mckenzie, B., Allemandi, L., Enkhtungalag, B., Do, H.T.P., Naidoo, P., Farrand, C., Waqanivalu, T., Cobb, L., Buse, K., Dodd, R., 2022. Implementing effective salt reduction programs and policies in low- and middle-income countries: learning from retrospective policy analysis in Argentina, Mongolia, South Africa and Vietnam. Public Health Nutr. 25 (3), 805–816. https://doi.org/10.1017/S136898002100344X.
WHO. (2023). Saturated fatty acid and trans-fatty acid intake for adults and children: WHO guideline. ⟨https://iris.who.int/bitstream/handle/10665/370419/9789240073630-eng.pdf?sequence= 1⟩. Accessed January 16, 2025.
World Health Organization. (2015). IARC Monographs evaluate consumption of red meat and processed meat and cancer risk. International Agency of Research on Cancer, October, 1–2.
World Health Organization. (2024). WHO global sodium benchmarks for different food categories. Second Edition. ⟨https://www.who.int/publications/i/item/9789240092013⟩. Accessed January 16, 2025.
Zampelas, A., Magriplis, E., 2019. New insights into cholesterol functions: a friend or an enemy? (MDPI AG). Nutrients 11 (7). https://doi.org/10.3390/nu11071645.