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Original Research Article

Comparison of a sodium-based and a chloride-based approach for the determination of sodium chloride content of processed foods in the Netherlands

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ABSTRACT

This study reports and discusses the sodium content of a set of 1016 processed food samples collected in the Netherlands, which covered 10 food groups (cakes/pastries, chips/nuts, sauces, processed meat, conserves, snacks, ready-to-eat products, cheese, bread, and soups) and 100 food commodities. The food groups that showed highest sodium contents were processed meat (1030 mg Na 100 g^{-1}), cheese (820 mg Na 100 g^{-1}), and sauces (752 mg Na 100 g^{-1}). Lowest sodium concentrations were determined in conserves (286 mg Na 100 g^{-1}), cakes/pastries (322 mg Na 100 g^{-1}), and soups (355 mg Na 100 g^{-1}). In addition, two different approaches for the assessment of sodium chloride content in the same sample set have been compared for all 1016 samples: determination of sodium by flame emission spectroscopy and determination of chloride by potentiometric titration. The sodium chloride content was then calculated converting the sodium and chloride content into the corresponding salt (NaCl) content. For the NaCl contents determined by the two approaches, significant differences for seven out of the ten food groups were observed, and the sodium contents of nearly half of the commodities showed significantly different NaCl levels. At food group level, the NaCl contents calculated from sodium were significantly higher ($p < 0.05$) than the NaCl content calculated from chloride for cakes/pastries, processed meat, snacks, cheese and soups, whereas it was significantly lower for the chips/nuts and the bread group. These differences can be explained by additional sources of sodium and/or chloride, e.g. certain food additives and the natural sodium and chloride content of the ingredients. Although most legal recommendations specify NaCl levels, the present study shows that sodium and chloride concentrations do not go necessarily hand in hand since they may originate from different sources.

1. Introduction

There is a general consensus that excessive dietary salt intake throughout life causes an increase of blood pressure with age (Havas et al., 2007) which perpetuates the risk of cardiovascular diseases (Ezzati et al., 2002; Turnbull, 2003). Those adverse health effects are related to the osmotic activity of sodium ions in extracellular fluids (He and MacGregor, 2010). Salt and sodium are often used synonymously but it is important to note that only sodium contributes to the adverse health effect associated with salt. A high sodium diet represents thus a serious health risk for humans according to the World Health Organization (WHO, 2006) and the European Union (European Commission, 2012). Therefore, it is well established that a reduction of sodium intake will lower blood pressure, with great individual and population health benefits. In Finland, a 30–35% reduction in sodium intake was achieved over the past 30 years which contributed to a 75% drop in mortality caused by coronary heart diseases in adults under 65 (Laatikainen et al., 2006). Apart from health benefits, sodium reduction strategies led by governments together with the food industry proved to be highly cost-effective (Murray et al., 2003; Asaria et al., 2007). Evidently, several Governmental organisations are currently committed in lowering overall sodium intake. The British Food Standards Agency, for instance, has started a national salt reduction initiative in 2003 by collaborating with food industry and by launching educational campaigns (Webster et al., 2011).

Currently in the Netherlands, the average salt consumption in adults amounts to about 9 g day^{-1}, which corresponds to 3.6 g

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day^{-1} of sodium (van Rossum et al., 2012). The Dutch Health Council that advises the Dutch government recommends a maximum of 6 g day^{-1} of salt (2.4 g day^{-1} of sodium). In comparison the WHO recommendation for a maximum salt intake of 5 g day^{-1} (2 g day^{-1} of sodium) is slightly lower.

Several methodologies are being used to assess the concentration of sodium chloride in foods which are based on the determination of either sodium or chloride which in turn are converted to the sodium chloride concentration. By using either sodium or chloride to determine the sodium chloride content in food it is assumed that sodium chloride is by far the major contributor to their levels in food. Unfortunately this is not always the case since sodium salts other than sodium chloride are added to food products for specific technological reasons as food additives and an additional source of sodium in processed foods is often naturally occurring in raw materials or ingredients. The same holds for additional sources of chloride.

The aims of this study are (1) to compare two different approaches for the assessment of sodium chloride in foods, one based on the determination of sodium by flame emission spectroscopy and the other based on the determination of chloride by potentiometric titration and to examine sources of discrepancy and (2) to evaluate the sodium content in various processed foodstuffs so as to provide an overview of the sodium content of products available on the Dutch market.

2. Materials and methods

2.1. Reagents

All the reagents were of analytical grade. For the analysis of sodium, sodium and potassium standard solutions (1000 μg mL^{-1} in 2% HNO_3) were from Ultra Scientific (Wesel, Germany), calcium standard solution (1000 μg ml^{-1} in 0.5 M HNO_3) was from Merck (Darmstadt, Germany). Nitric acid (65% m/m) was from J.T. Baker (Deventer, the Netherlands), and hydrogen peroxide (30% m/m) was from Merck. Certified reference materials LGC 7103 (sweet biscuits) and BCR 063R (skimmed milk powder) were purchased from LGC standards (Tennington, UK). For chloride analysis, silver nitrate (0.1 M $AgNO_3$), potassium nitrate, nitric acid (65% m/m), sodium chloride and PVA (polyvinyl alcohol) were purchased from Merck.

2.2. Sampling

Over a period of 6 months, from May to November 2011, a total of 1016 packaged foods were sampled at various supermarkets all over the Netherlands by the Netherlands Food and Consumer Product Safety Authority (NVWA). Food products were selected for inclusion in the present study on the basis of their known contribution to the overall sodium intake in the Netherlands. They were categorized in 10 food groups: cakes/pastries, chips/nuts, sauces, processed meat, conserves, snacks, ready-to-eat products, cheese, bread, and soups. Within each group, 10 food commodities were identified. For each commodity a variable number of brands were sampled and one sample was analysed for each brand. The numbers of samples per food group and commodity are specified in Table 1.

For each food sample, information was collected with regard to brand and product name, composition, type of packaging and storage conditions, the presence on the label of health claims or quality labels. Moreover, pictures were taken of each food sample. All data were collected manually onto a standardised data collection sheet and quality control procedures were implemented to ensure correct data entry.

2.3. Procedures

2.3.1. Sample preparation

After arrival in the laboratory, the samples were immediately homogenized and analysed. Bread was dried prior to analysis. To this end, a portion of bread (a cube of approximately 1 cm^3) was pre-dried in a metal oven for 6 h at 60 ± 2 °C and then dried for 12 h at 103 ± 2 °C. Dry soups were prepared according to the instructions on the package. Cheese was milled by means of a rasp. Cookies, chips, nuts, meat and similar products were ground in a laboratory food processor. To ensure an homogeneous sampling after grinding, snacks, biscuits with peanuts, almond paste and/or chocolate, pizza and other heterogeneous products were ground after freezing with liquid nitrogen. Sauces were mixed and soups were blended by Ultra-Turrax® (IKA, Staufen, Germany).

2.3.2. Quantification of salt by determination of sodium by flame emission spectroscopy

For analysis 350 mg ± 10 mg homogenized sample was weighed in a quartz vial insert. Three mL nitric acid were added and the quartz vial was weighed without the cover (mass A). Then the quartz insert keg was placed in a pressure vessel with 6 mL of 12.5% H_2O_2 solution. The pressure vessel was placed in the microwave with a PC controlled temperature program (model Ethos one; Milestone Inc., Shelton, US) and digested according to the following program: 0 min, 20 °C; 0–15 min, 20–200 °C; 15–40 min, 200 °C; 40–60 min, 200–20 °C. The quartz insert keg was taken out of the pressure vessel by tweezers and cooled down by rinsing the outside with demineralised water and dried with a tissue. Subsequently the quartz keg was weighed and brought to mass A again with nitric acid. The digested sample was quantitatively transferred to a 50 mL plastic tube and made up to a final weight of 51.30 g (±0.05 g) with demineralised water. Two mL of the resulting solution was transferred to a plastic tube, diluted 10 times with 18 mL of demineralised water and thoroughly mixed prior to analysis. The solution was further diluted with a 0.39% nitric acid solution if necessary. Sodium was analysed by a flame photometer (Model 420 Flame Photometer; Sherwood scientific LTD, UK) with propane/butane flame at a wavelength of 589 nm. Prior to analysis the spectrophotometer was stabilized for 30 min with demineralised water. A calibration curve was built in the range 0.00–5.00 mg L^{-1} (six standard solutions). A 0.39% nitric acid solution was used as blank. The method was validated according to standard ISO 17025 guidelines with the following certified reference materials: LGC 7103 (sweet biscuits) and BCR 063R (skimmed milk powder). The method performance characteristics were as follows: Recovery values: 102.1% for biscuits and 92.8% for skimmed milk powder; Coefficient of variation of repeatability (RSD_r): 3.0% for sweet biscuits and 0.4% for skimmed milk powder. Limit of detection (LOD): 0.23 g kg^{-1}; Limit of Quantification (LOQ): 0.46 g kg^{-1}. For the calculation of sodium chloride content, the amount of sodium was multiplied by 2.541×10^{-4} and the sodium chloride was expressed as g NaCl 100 g^{-1} (NaCl%). A single measurement was carried out in each sample.

2.3.3. Quantification of salt by determination of chloride by potentiometry

The chloride content was determined according to standard method NMKL 178, 2004 (NMKL, 2004). The analysis consists of a potentiometric precipitation titration using a silver nitrate solution as titrant. A variable amount of sample (depending on chloride concentration) was mixed with water and 5 mL of a nitric acid solution (4 mol L^{-1}) and allowed to rest for 10 min. The resulting solution was then homogenized by using an Ultra-Turrax and titrated using a 0.1 mol L^{-1} silver nitrate solution. This solution was previously standardized using a 0.1 mol L^{-1} sodium chloride solution. The titrations were performed using an Ag titrode (model 6.0430.100, Metrohm, Herisau, Switzerland) The