Food and Chemical Toxicology 111 (2018) 329–340

Contents lists available at ScienceDirect

Food and Chemical Toxicology

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

Benefit and risk assessment of increasing potassium intake by replacement of sodium chloride with potassium chloride in industrial food products in Norway

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ARTICLE INFO

Keywords:
Benefit and risk assessment
Intake estimates
Potassium
Sodium
Vulnerable groups

ABSTRACT

High sodium chloride (NaCl) intake is associated with health risks. NaCl may be replaced by potassium chloride (KCl) to decrease sodium intake. However, increased potassium may also have negative health effects. We conducted a benefit and risk assessment of increasing potassium by ratios of 30:70, 50:50, 70:30 (weight % K^+: weight % Na^+) in children, adolescents and adults in Norway, using intake data from national food consumption surveys and available literature on potassium health effects. An intake of at least 3.5 g/day of potassium decreases risk of stroke and hypertension, and this level was used in the benefit assessment of the healthy population. Three g/day of potassium added to mean food intake is assumed safe, and these levels were used in the risk assessment. Not all persons reached the protective level of potassium, and increasing numbers exceeded the safe levels, in these scenarios. In addition, elderly above 85 years and infants below one year of age, as well as several patient groups and medication users, are particularly vulnerable to hyperkalemia. In conclusion, the number of Norwegians facing increased risk is far greater than the number likely to benefit from this replacement of sodium with potassium in industrially produced food.

1. Introduction

The World Health Organization (WHO) and the European Union (EU) have developed strategies to reduce sodium chloride (NaCl, "salt") intake in the population (WHO, 2006; The Council of the European Union, 2010). Since 2008, Norway has joined this strategy, and in 2011, the former Norwegian National Nutrition Council prepared a strategy aiming at reducing the sodium chloride intake in the Norwegian population (Norwegian National Nutrition Council, 2011). High sodium chloride intake is associated with development of high blood pressure and is a risk factor for cardiovascular disease (CVD), stroke and kidney disease. In 2012, WHO strongly recommended a reduction in sodium intake to lower blood pressure and thereby the risk of blood pressure-related disorders in both adults and children (WHO, 2012a). A reduction to less than 5 gram sodium chloride per day was recommended for adults, and for children this value should be adjusted based on their energy requirements (WHO, 2012a). There is still no definite explanation for why sodium chloride increases blood pressure (Garfinkle, 2017; Titze and Luft, 2017).

Sodium chloride has several functions in processed foods. It adds flavour, preserves, increases the binding of water to proteins in meat and fish and has additional technological functions in the production of bread and cheese. In the diet, approximately 3/4 of the sodium chloride comes from industrially produced foods (Norwegian National Nutrition

Abbreviations: ACE, angiotensin-converting enzyme; AI, adequate intake; CI, confidence interval; CVD, cardiovascular disease; FFQ, food frequency questionnaire; HR, hazard ratio; KCl, potassium chloride; NaCl, sodium chloride; NSAIDs, non-steroidal anti-inflammatory drugs; RCT, randomised controlled trial; RR, relative risk

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https://doi.org/10.1016/j.fct.2017.11.044
Received 18 March 2017; Received in revised form 20 October 2017; Accepted 20 November 2017
Available online 22 November 2017
0278-6915/

Council, 2011). Reducing the use of sodium chloride in industrial food production may thus result in a reduction of the sodium chloride intake by the population.

Sodium chloride may be replaced by potassium chloride (KCl) in industrially produced food in order to decrease sodium intake. However, the increased potassium may have negative health effects. Potassium chloride (E508) is regulated in Europe by the Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December (EU, 2008), which states that potassium chloride may be added "*quantum satis*" to food, i.e. the amount necessary for its function, but not higher. This was implemented in Norwegian regulation in 2011 (HOD, 2011).

The National Institute for Health and Care Excellence in United Kingdom discouraged the use of potassium and other substitutes to replace sodium chloride (NICE, 2010). The aim of avoiding potassium substitution was twofold: to help consumers get used to less salty foods and to avoid additives which may have other potentially adverse effects on health.

The absorption of potassium is effective and about 90% of the dietary potassium is normally absorbed from the gut. The total body potassium is approximately 135 g in a 70 kg adult. Of the total body stores, about 98% is located in the intracellular fluid, whereas the extracellular compartment contains the remaining percentage (Traeger and Wen, 2008). The concentration of potassium in plasma is tightly regulated within the narrow range of approximately 3.5–5 mmol/L (135–195 mg/L). The body is able to handle high intakes of potassium without any substantial change in plasma concentration, by synchronised alterations in renal excretion and cellular uptake or release. Tight regulation of the potassium level is essential for the membrane potential of cells, and thereby for nerve and muscle function, blood pressure regulation and cardiac function, as well as for other functions (Taber and Thomas, 1997).

Hyperkalemia, defined as plasma potassium concentration higher than 5.0 mmol/L, may result from release of potassium from tissues and/or inadequate renal potassium excretion. Impaired renal excretion of potassium may be caused by disease states such as renal malfunctioning, hypoaldosteronism and Addison disease, and/or treatment with potassium-retaining drugs such as angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers, β-blockers and non-steroidal anti-inflammatory (NSAID) drugs. However, there is no evidence of adverse effects from increased dietary potassium in individuals with unimpaired potassium excretion (NNR, 2012; WHO, 2012b).

Hypokalemia, defined as plasma potassium concentration below 3.5 mmol/L, may develop as a consequence of increased losses from the gastrointestinal tract and kidneys, for example during prolonged diarrhea or vomiting, in connection with use of laxatives or diuretics or after high intake of licorice. Potassium deficiency due to low dietary intake is uncommon due to the presence of potassium in most foods (Traeger and Wen, 2008; EFSA, 2005; NNR, 2012).

Sodium chloride (NaCl) may be replaced by potassium chloride (KCl) in industrially produced food in order to decrease sodium intake. However, in spite of potassium's essential functions in the body and beneficial effects, the increased potassium may also have negative health effects. We therefore conducted a benefit and risk assessment of increasing potassium by ratios of 30:70, 50:50, 70:30 (weight % K^+: weight % Na^+) in children, adolescents and adults in Norway on request from the Norwegian Food Safety Authority, using intake data from national food consumption surveys and available literature on health effects of potassium.

2. Materials and methods

The levels of potassium having beneficial or adverse effects were obtained from previous risk assessments and publications retrieved by literature searches in this benefit and risk assessment on the Norwegian population.

2.1. Literature searches and previous reports on beneficial and adverse health effects of potassium

Literature searches were conducted to retrieve scientific documentation for beneficial effects of potassium in the general population, and for adverse effects in the general population and in groups that are particularly vulnerable to potassium. Test searches were conducted to find relevant terms, search words and controlled vocabulary (MeSH and EMTREE). For beneficial effects, the following search strings were used: Potassium in title AND Meta-Analysis (as MeSH-term) OR meta-analysis* (as text word), and a search was conducted in Medline. Publications in English, Norwegian, Danish and Swedish without limitations in publication year were included. The search was conducted in June 2013 and resulted in 47 hits. Another search was conducted in January 2014, but no relevant new systematic reviews or meta-analyses were found.

Initially, the titles and abstracts of all papers identified in the search were independently assessed for relevance by two reviewers. Sixteen meta-analyses and systematic reviews including papers investigating clinically relevant health outcomes were selected. In the next step, full text articles were assessed by one person. Non-systematic reviews, papers reporting not clinically relevant health effects and papers including other substances together with potassium were excluded. Eight systematic reviews and meta-analyses were included in the results. In February 2017, four new relevant papers published since 2014 and an opinion from the European Food Safety Authority (EFSA) on dietary reference values for potassium were also included in this assessment, based on the same criteria as before.

For adverse effects, literature searches were conducted in Medline, Embase and ISI web of Science. The search terms included potassium in title, and the following words in the title, abstract, subject heading, name of substance, or registry word fields: food* OR dietary intake OR diet* AND adverse effect* OR adverse reaction* OR risk factor* OR health risk* OR risk assessment*. The search was limited by requiring that potassium should be in the title, by excluding animal studies and by limiting the languages to English, Norwegian, Danish, Swedish and German. Since it was assumed that relevant literature published prior to 2004 was covered by EFSA's "Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the Tolerable Upper Intake Level of Potassium" (EFSA, 2005), the search was limited to publications from 2004 onwards. The search resulted in 60 publications. Publications were excluded if adverse health effects related to dietary intake of potassium were not addressed. One reviewer assessed the titles and abstracts of all publications identified in the search process for relevance, and then the full text versions of potentially relevant articles. Additional articles were retrieved by other PubMed searches, and these searches were not limited by publication year. In addition to the publications retrieved by the literature searches, reports from other risk assessment institutions were used. Searching the reference lists of these reports also resulted in some relevant publications.

2.2. Intake calculations of sodium and potassium from the national food consumption surveys

Intakes of sodium and potassium were computed from participants in Norwegian dietary surveys (Norkost 3, Småbarnskost and Ungkost, 2000) by the software system (KBS) developed at the Institute of Basic Medical Sciences, Department of Nutrition, at the University of Oslo. The food databases are mainly based on different versions of the official Norwegian food composition table (FCT, 2016; Rimestad et al., 2000). For calculation of the three different scenarios (K^+:Na^+ in ratios of 30:70, 50:50, 70:30), first the naturally occurring sodium in food, 12% of calculated intake, was subtracted (EFSA, 2005). Then the percentages in the three scenarios were calculated from the remaining sodium intake where sodium was replaced by potassium weight % by weight %