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Salt Iodisation of Processed Foods in Germany: Evidence, Processors' Perceptions and Implications for Public Health*

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Salt Iodisation of Processed Foods in Germany: Evidence, Processors' Perceptions and Implications for Public Health

Abstract

Purpose

We provide primary data on salt iodisation of processed foods in Germany, analyse reasons for food processors' use or non-use of iodisation and derive implications for public health.

Design/methodology/approach

Statistical evidence is presented on the use of iodised salt in bread and bakery products, meat and meat products and dairy products in the German grocery-retailing sector. Information is based on mobile data collection in a representative sample of grocery stores in four German cities. These data are analysed with logistic regression models. Additionally, an online survey of bakers and butchers is utilised to record and to explain the use of iodised salt in specialised food stores.

Findings

Salt was added in 69.3% of the 29,910 foods analysed in the market study. When salt was added, iodised salt was used in only 28.5% of the cases. According to the online survey, only 44% of the bakers and butchers used iodised salt, and the user share declined over time. Incomplete information from processors on the role of iodised salt for public health is contributing to the low and declining user share.

Originality/value

We combine different market research methods and elaborate that the recommendation by the German Federal Ministry of Food and Agriculture – “If salt, then iodised salt” – is implemented to a very limited extent by the food industry and specialised food stores. From the behaviour of food processors and their perceptions of salt iodisation we gain new insights for policy and public health.

Keywords: Salt iodisation, Processed foods, Market research methods, Food retailing, Germany

1 Introduction

The amount of salt intake is an important target variable of nutrition and health policy. A lower salt intake reduces blood pressure (Frisoli *et al.*, 2012) and the risk of cardiovascular diseases (He and MacGregor, 2011). Therefore policies have been implemented (Trieu *et al.*, 2015) or recommended in many countries to reduce salt intake for health reasons. Another target variable of health policy is the iodine content in salt. As an essential component of thyroid hormones, iodine affects metabolic processes in the human body. Health implications of iodine deficiency are goitre, reduced work capacity and mental retardation among adults and impaired brain development and stunted growth among children (Zimmermann, 2009). To prevent and control the negative health consequences of iodine deficits (WHO, 2014a) the World Health Organisation recommends universal salt iodisation as a cost-effective strategy that should be used as a complementary and flexible tool in combination with salt reduction (WHO, 2014b).

In Germany, salt intake and iodine fortification are addressed by various health policies. The “Reduction and Innovation Strategy” in Germany (BMEL, 2018) is a concerted action between the public sector and the food industry with the objective to reduce the salt content in processed foods by reformulation strategies. Apart from this supply-side approach, efforts to reduce salt intake include nutrition information campaigns. Concerning iodised salt, Germany relied on information campaigns as well as on various legislative initiatives to achieve the iodine fortification of salt and a wide distribution of iodised salt in the

retailing sector. Iodine fortification is voluntary in Germany and legislation is described in more detail elsewhere (Food Fortification Initiative *et al.*, 2019). At the household level, the usage of iodised salt has been allowed since 1981 (still voluntary) and for industrialised food production, restaurants and canteens since 1989. Follow-up guidelines allowed the usage of iodised salt in cheese production and meat processing, too. Fortifying animal fodder has been permitted since 2005. The policy instruments targeted at a wider use of iodine fortification were particularly successful in the 1980s and 1990s in raising the share of iodised salt in private households and, to a lesser extent, in the food industry (Scriba *et al.*, 2007).

There is additionally a detailed legal regulation of the definition and labelling of salt and iodised salt. Standards for food-grade salt are set by the Codex Alimentarius. Table salt consists predominantly, by 97% or more, of sodium chloride (NaCl) and is obtained from the sea, from underground rock salt or from natural brine. In Germany, table salt can be iodised with sodium iodate or potassium iodate with 15-25 mg/kg salt. If table salt is iodised, its different compounds have to be declared on the list of ingredients. The term "salt" has to be replaced then by, e.g., "iodised salt (salt, sodium iodate)".

Although considerable progress has been made worldwide to overcome iodine deficiency, the intake of iodine has remained insufficient at least for subgroups in the German population. The German Health Interview and Examination Survey for Adults (DEGS) and for Children and Adolescents (KIGGS) revealed in both 2006 and 2011 that the iodine intake of about 1/3 of the population of adults and of 14-17 years old adolescents was below estimated average requirements (EAR) (Johner *et al.* 2016; BMEL, 2020). Later analyses have indicated a subsequent deterioration in the iodine status of German schoolchildren and, most recently, even a return to an iodine-deficit country based on the median iodine intake in the adolescent group (Esche *et al.*, 2019; BMEL, 2020).

Processed foods are the primary source of salt intake in industrialised countries such as Germany (Brown *et al.*, 2009). Thus, salt iodisation of processed foods plays a key role for the iodine status of the population (WHO, 2014a; Arbeitskreis Jodmangel e.V., 2021). There is a tendency, however, for iodine intake in industrialised countries to be mainly based on table salt in the households rather than from added salt in processed foods (Ohlhorst *et al.*, 2012). This seems to be the case in Germany as well. From 2005 to 2015 between 70 and 80% of the purchases of table salt in Germany were iodised salt (Großklaus, 2017). A recent German project, based on a mixed-methods approach with various qualitative and quantitative techniques, confirmed a clearly lower use of iodised salt by food processors. Whereas a German-language project report contains many detailed results (Bissinger *et al.*, 2018), in this article we provide a selection of the major quantitative results and relate those to the most recent literature on salt iodisation.

The objective of this article is threefold. We intend (i) to provide a very concentrated summary of major quantitative results on salt iodisation of processed foods in Germany and reasons for the use or non-use of iodised salt, (ii) to clarify the role of processors' perceptions, and (iii) to discuss the implications of the results for public health. Different market research methods are used to cover processed foods supplied by the food industry and by specialised food stores. First, mobile electronic data collection was utilised in selected retail stores to compile the use of salt and iodised salt for a full census of manufactured food

products in three major food groups: bread and bakery products, meat and meat products, and milk and milk products, hereafter referred to as *bread*, *meat*, and *dairy*. Secondly, an online survey was addressed to German bakeries and butchers' shops to investigate the use of and perceptions of iodised salt in these important types of specialised food stores.

2 Methods

Data collection in the retail sector: study design and sampling

In March, April and October 2017, primary data were collected in food-retailing facilities to assess the proportion of processed foods in the food groups *bread*, *meat*, and *dairy* that contain iodised salt. The food group *bread* covers bread in general, bread rolls, dishes based on bread, crispbread, bread chips and other bread products. The food group *meat* contains raw meat, meat products, sausages, and dishes based on meat. The food group *dairy* includes milk drinks, milk products, cheese and quark. These groups are very similar to the food groups “*bread and cereal products*”, “*meat, meat products and sausages*” and “*milk, milk products and cheese*” which are the most important food groups for overall salt intake according to the German National Nutrition Survey II (Heuer *et al.*, 2015).

Three major types of retailers are prevailing in the German food-retailing sector: discounters, supermarkets, and hypermarkets. Whereas discounters are defined according to their everyday-low-price strategies, hypermarkets and supermarkets are defined by their sales area. Hypermarkets (German: SB-Warenhäuser) typically combine a supermarket with a department store and are characterised by a sales area of 5000 m² or more. Similarly to international definitions, we define supermarkets as all other full-range food providers. In a more detailed German classification, these include large supermarkets (2500 to 4,999 m² sales area), smaller-scale supermarkets (400 to 2,499 m² sales area) and small food retailers with a sales area below 400 m². These three types of full-range grocery retailers cover most food purchases by private households in the food groups *bread*, *meat* and *dairy* in Germany. In 2015, the market shares of the three types of full-range grocery retailing (of discounters) reached peak values of more than 90% (50%) in the group *dairy* for cheese, drinking milk and yogurt (BMEL, 2016). In Germany, however, it is striking that the food groups *bread* and *meat* were purchased to a significant extent in specialised food stores. In 2015, 35% of bread and 15% of meat and meat products are purchased in specialised stores such as bakeries¹ or butchers' shops². Given this evidence, special emphasis is given to full-range grocery stores including the discounters in the retail-level study and to bakers and butchers in the online survey.

Throughout Germany, there were approximately 37,700 food stores in 2016 (EHI Retail Institute, 2017). At the time of the study the most important were: Edeka, Lidl, Rewe, Aldi Süd, Netto Marken Discount, Kaufland, Aldi Nord, and Real. Sampling of the food retailers was conducted based on the revenue shares

¹ In Germany bakeries offer a wide range of bread, rolled bread and buns as well as sweet buns, cakes and Danish pastries. Often these bakeries also offer coffee to go and buns with cheese and/or bacon. They often have the selling point attached to the actual bakery and additional selling points in a specific geographic area around the bakery.

² The butchers' shops in Germany offer a wide range of meat and meat products as well as various sausages. In addition some butchers offer a party service and or ready meals to take away. They often have the selling point(s)/shop(s) near their own slaughterhouse.

of the three major types of full-range grocery retailers: discounters (48%), supermarkets (37%) and hypermarkets (15%). The study was also designed to convey a picture of the North, South, East, and West of Germany in the selection of grocery stores. Given the similar size of the cities, the survey took place in Hannover, Düsseldorf, Dresden, and Stuttgart. As the large retail firms typically rely on nationally or at least regionally uniform assortment strategies, the empirical results that follow can be regarded as adequately representative for the available foods in the large German retail chains. The objective was to approximate the market shares of the major retailer types to the store sample in the four cities. Of the top 10 retailers in 2016, it was possible to include seven in the data collection. Four hypermarkets (Kaufland), 11 supermarkets (three Edeka, four Rewe, and four Rewe City markets) and 10 discount stores (one Aldi Nord, two Aldi Süd, four Penny, and three Norma markets) were considered.

Prior to any data collection, the management of each selected food retailer was contacted to seek permission to conduct a census of all products in the selected food groups. Where permission was granted, a team of trained enumerators recorded relevant details like shelf type, type of production, i.e. organic or conventional, whether wholegrain, volume or weight, price, product name, manufacturer, type of salt and salt content. The information provided on the label or packaging of the processed products, in the list of ingredients, and/or the food composition table was used. The data were recorded via tablet computers and managed with the Open Data Kit software for mobile data collection (ODK Community, 2018).

The recorded products were allocated to one of the three food groups and their subgroups primarily according to the National Consumption Survey List (NVS II) (Heuer *et al.*, 2015). If necessary, labelling information on the main ingredient was used for the allocation to a food group.

Statistical and econometric analysis of the retail-level data

Apart from frequency distributions on salt iodisation in processed foods, the retail-level data were used for a multivariate analysis based on logistic regression. Independent variables (X) were identified which determine the use ($Y = 1$) or non-use ($Y = 0$) of iodised salt in the processed foods. The so-called ‘odds’ (change from $Y = 0$ to $Y = 1$) were introduced in the logistic regression. Odds measure the ratio between the probability of the use of iodised salt in processed foods ($Prob_i(Y = 1 | X = x_i)$) and the corresponding counterprobability that no iodine salt is processed ($Prob_i(Y = 0 | X = x_i)$):

$$(1) \text{ Odds } [Prob_i(Y = 1 | X = x_i)] = \frac{Prob(Y = 1 | X = x_i)}{1 - Prob(Y = 1 | X = x_i)} = \frac{Prob(Y = 1 | X = x_i)}{Prob(Y = 0 | X = x_i)}$$

Standard logit regression is not only about odds but also about odds ratios. Ratios are obtained by transforming equation (1) and its logarithmic function into a single one. This transformation then leads to the odds ratios, in which e^{β_1} represents the effect coefficient of the vector of variables X (Gujarati, 2015):

$$(2) \text{ Odds } (Prob_i = 1 | X = x_i) = \frac{(Prob)}{1 - (Prob)} = e^{\beta_0 + \beta_1 x}, \text{ with } e^{\beta_1} = \frac{\text{Odds}(Prob_1)}{\text{Odds}(Prob_0)}.$$

Different models were specified in the multivariate analysis for the two food groups with the highest share of products with added salt, i.e. *bread* and *meat*.³ We included independent variables in the model which have been claimed in the literature to affect the use or non-use of iodised salt by processors. In particular, it has been argued that (i) iodised salt might be avoided since prices are higher than for non-iodised table salt, and (ii) iodised salt is partly substituted by trendy salts like sea salt, at least in processed foods that are perceived by consumers to be high-quality foods. Therefore, we consider independent variables that stand for the price level of a product and its image as high-quality food. Furthermore, we posit that a higher salt content or the use of more than one salt type will raise the probability that iodised salt has been used. Additionally, a number of control variables (*Z*) are incorporated that characterise the food retailers, the retailer's location, subcategories of the foods, or the size of the manufacturers with dummy variables. Equation (3) represents the underlying logit function with the following variables:

$$(3) \text{ Logit} = f \{ \textit{wholegrain/organic}, \textit{store brand}, \textit{price}, \textit{high salt content}, \textit{salt additives}, \textit{Z} \}$$

The variables *wholegrain* and *organic* are often perceived as high-quality characteristics in the food groups *bread* and *meat* respectively. As most organic bread and bread products are made of wholegrain, the variables *wholegrain* and *organic* were not introduced jointly in the logit model to avoid multicollinearity. The price level of the individual foods (*price*) is computed as a metric variable in €/100g. Moreover, the variable *store brand* captures all products offered by retailers under their names in contrast to the national brands of the food industry. Store brands are often a cost-saving alternative to national brands. We transformed the metrically scaled salt content into a dummy variable. The binary variable is coded 1 for *high salt content* and 0 for a low salt content (reference category). The threshold value for this grouping is a salinity of 1.27 g salt per 100 g product weight in *bread*. For *meat*, the threshold is 2.39 g salt per 100 g. The variables *two salt additives* and *three salt additives* describe the respective number of salts added. This captures the fact that a product may have one salt additive or two or three and the first (second, third) will be the salt with the highest (second-highest, third-highest) weight share. All variables in the models, except for price, are dummy variables and coded “1” when the event occurs and otherwise “0”.

Sample selection and study design of the online survey

Whereas the retail-level study covers manufactured foods produced by the bakery and the meat-processing industry, the online survey was targeted at butchers and bakers selling their products in their own stores. Both artisan producers and larger firms organised in a branch system are included where the latter group combines centralised production with decentralised stores. In total, 1,982 bakers and butchers across Germany were invited to participate in the online survey between 31 January and 26 February, 2018. One reminder email was sent in mid-February 2018. The email addresses of the butchers were identified via

³ All bread and meat products that did not contain table salt were excluded from the logistic analysis. In the food group *bread*, 78 products were excluded that did not contain salt and 24 products for which no information was provided in the respective list of ingredients. In the case of the food group *meat*, this mainly concerns the subcategory of unprocessed meat products, to which salt is, naturally, not added.

internet-based research (n = 1,102). Most of the butchers were found in Bavaria and just a few in Hamburg. The distribution of the butchers was a good match with the distribution found in other studies (Fleischwirtschaft.de, 2017). The email list of the bakers (n = 880) was identified from a list of the 1,000 bakers with the highest turnover (Rentsch, 2017). The online questionnaire included three parts: (i) introductory questions about the location and size of the enterprise; (ii) questions about the use of iodised salt in order to group the respondents under general iodised salt users, mixed salt users and non-iodised salt users; (iii) a section about knowledge, attitudes and the use of salt in current and past food processing.

3 Results of the retail-level study

The overall sample contained 30,345 different products in the food groups *bread*, *meat*, and *dairy*, of which 435 products were excluded since it could not be ascertained whether salt was added. Therefore the sample for the following statistical analysis is 29,910 products. *Bread* accounted for 13% of the statistical sample, with 3,928 products being collected in 25 stores in four cities in Germany. *Meat* and *dairy* accounted for 44 and 43% respectively of the analysed sample, with 13,140 meat and 12,842 milk products. Clustering for different stores and the locations revealed comparable shares for each food group. As expected, the largest product variety was offered by hypermarkets, followed by supermarkets. Discount stores included in the underlying sample offered a smaller range of bread, meat, and dairy products than hypermarkets and supermarkets.

Statistical evidence on salt iodisation in the food groups bread, meat and dairy

Table I provides aggregate data on the use of salt, iodised salt, sea salt and non-iodised salt in processed foods of the food groups *bread*, *meat* and *dairy*. The data reveal that salt was added during the production process of 69.3% of all products under consideration. In the food groups *bread* and *meat* in particular, salt is a main ingredient. Salt is less important in the food group *dairy*. In total, 98% and 87% of all products included in the food groups *bread* and *meat* contain salt but only 42% of the *dairy* products. Overall, the product category table salt (also known as boiled salt, rock salt, or evaporated salt) is widely used in food production. Another important component of bread and dairy products is sea salt, with shares of 10.2% and 1.7% in the food groups *bread* and *dairy* respectively. Nitrite salting was used in around 8% of the foods in the *meat* group. Some further non-iodised kinds of salt are specific to individual products. Large-grained salt, for instance, is used for pretzel-type items, and some kinds of cheese mellow in brine. Table I already reveals that the share of non-iodised types of salt is rather large. Only 19.7% of all analysed and only 28.5% of all salted products were produced with iodised salt, which accounts for 5,906 products over all three categories. There is considerable potential for increasing the use of iodised salt in the industrial production of bread, meat and milk products. The use of iodised salt varies greatly between the food groups and across products within the food groups. For salted products in the food group *meat*, the share of products with iodised salt is highest with 47%. 10% of salted products in the food group *bread* but only 2% in the food group *dairy* were produced with iodised salt.

Please insert Table I here

Clustering for different subcategories of each product category underlined the first impression. The list of ingredients in (salted) *dishes made of bread* included iodised salt in nearly 30%, followed by (salted) *bread rolls*. Salted *meat* products with the highest share of iodised salt are *meat & sausages* (50%) and *dishes made of meat* (38%). There were some differences between sales lines and, to some extent, within sales lines as well. This may be explained by differential product assortments within the various sales lines. Discount stores used to have the highest percentage share of products being produced with iodised salt (especially for the two food groups *bread* and *meat*). Clustering for locations revealed that percentage shares of products being produced with iodised salt were comparable across cities.

Results of the logistic regression

Table II presents estimated results of the logistic regression for *bread* and *meat*, including the odds, standard errors and odds ratios.⁴ According to equation (3) the detailed estimates for the two food groups showed 15 and 17 statistically significant independent variables, which may explain the dependent variable of the respective logit model. Three test coefficients in Table II indicate the good explanatory power of the two models. Nagelkerkes pseudo- R^2 values point to an acceptable or good model fit (*meat*: ≈ 0.2 ; *bread*: ≈ 0.4). The χ^2 -test of the model coefficients is highly significant and indicates the explanatory power of the chosen independent variables. Additionally, the classification rate or count R^2 measures the percentage share of the number of observations that are correctly predicted by the estimated model (Gujarati, 2015). For the logistic regression of *bread (meat)*, 88.7% (68%) of the 2,843 (10,119) observations are correctly predicted by the model.

We are particularly interested in the question of how quality perceptions of consumers, price information and the overall salt content and structure affect the use of iodised salt in processed foods. Given the trend towards “natural” foods, alternative salt types such as sea salt are perceived and marketed as natural, too. Thus, iodised salt may be partly substituted in the use of, for example, wholegrain *bread* or organic *bread* and *meat*. This presumption is fully confirmed by the logit results. The coefficients of the variable *wholegrain* in the food group *bread* and the variable *organic* in the food group *meat* are highly significant and negative. Following equation (2), this indicates that the odds for the use of iodised salt fall if *bread* is *wholegrain* and *meat* is *organic* (dummy variables in both cases coded as 1). In terms of the odds ratio, the relative probability of using iodised salt changes by the factor 0.597 and, thus, declines by 40.3% ($= (1 - 0.597) \cdot 100$) for wholegrain compared to non-wholegrain *bread*. Analogously, organic meat is less likely to contain iodised salt than non-organic *meat*. Table II reveals negative odds and an odds ratio below unity for the *organic* variable. Estimation results for the *price* variable, either in linear form for *bread* or in logarithmic form for *meat*, show highly significant negative odds (for *bread*: -1.600; for *meat*: -0.971) and

⁴ 158 cases had to be excluded from the logistic regression for iodine salt used in bread products due to missing values so that ultimately 2,843 products were included in the regression for the food group *bread*.

odds ratios far below 1. The sign of the odds and the magnitude of the odds ratios indicate that an increase in the product price decreases the probability of *bread* and *meat* being produced with iodised salt.

The variable *store brand* increases the probability of *meat* containing iodised salt significantly. The positive β coefficient implies an increase in the odds whenever the dummy variable is coded “1”. According to the odds ratio, the relative probability of using iodised salt changes by the factor 1.835 and, thus, increases by 83.5% ($= (1.835 - 1) \cdot 100$) for *store brands* compared with the benchmark situation of producer brands. As store brands often represent cost-saving alternatives to producer or national brands, this suggests again that iodised salt is more likely to be used in processed foods in the lower-price segment. However, the variable *store brand* is not significant for *bread*.

Highly significant additional impacts arise from the general salt content and the number of salt additives. If a product has a *high salt content* rather than a low one, the odds ratio between the probability of using iodised salt and the probability of not using it during food processing increases significantly by a factor of 1.574 for *bread* and by 1.131 for *meat* or by 57.4 and 13.1% respectively. Hence, products with a higher salt content are more likely to contain iodised salt, in direct comparison with a product with a low salt content (reference).

If salt is added, the number of salt additives on the lists of ingredients is either one, two or three. We expect that iodised salt is more likely to be present in a product with more than one salt additive. This is confirmed by the econometric results. The odds ratios of the variables *two salt additives* (*bread/meat*: 5.57/3.47) and *three salt additives* (*bread/meat*: 7.601/2.343) are in all cases greater than one. This means that two or three salt additives compared with only one raise the probability that a product in the food groups *bread* and *meat* is produced with iodised salt. According to the odds, these results are highly significant.

Please insert Table II here

4 Results of the online survey

The food-manufacturing industry is responsible for only a proportion of processed foods. Bakers and butchers are also producers in the food groups *bread* and *meat*. Their specialised product assortments are important elements of German food distribution, and the retail-level analysis was complemented by an online survey among those specialised stores. The objective of the survey was to elicit information regarding (i) the use of iodised salt by bakers and butchers, and (ii) the reasons behind the use or non-use of iodised salt.

Out of the 1,982 specialised food processors we contacted, 223 responded with a complete questionnaire ($n = 101$ bakers; $n = 122$ butchers). 44% of firms in this group used iodised salt, either as the only salt type (26%) or as one of several salt types (18%). The share of firms using iodised salt was higher in the craft butcher's sector (49%) than in the baker's trade (39%). It is striking that 68% of the non-users among bakers and butchers stated that they had used iodised salt in the past. These few aggregate numbers confirm that the use of iodised salt by bakers and butchers is limited and has declined over time.

Tables III to V summarise important views of bakers and butchers on iodine fortification. Users of iodised salt received a set of statements designed to elicit responses that indicate their motivation for iodine

fortification. Analogously, non-users of iodised salt among the bakers and butchers were given a different set of statements, and their responses can be expected to illustrate the rationale for their non-use. The statements with the highest share of agreement are shown in Table III for the users and in Table IV for the non-users of iodised salt. Additionally, some statements are shown in Table V which received a relatively high share of neither/nor answers on the Likert scale by non-users of iodised salt. This can be interpreted as sign of imperfect information in this group on the role of salt iodisation.

As Table III reveals, bakers and butchers who use iodised salt clearly support the proposition that iodised salt contributes to health. There is a strong agreement, by 67% and more of the respondents with statements 1, 2, and 4 supporting this view. Tradition is another rationale. The tradition visible in the respondents' support of statements 2 and 3 may, however, indicate again the health benefits from using iodised salt that were expressed in government information campaigns years ago. A majority of bakers and butchers who use iodised salt stress additionally in their reaction to statement 5 that iodised salt has no price-raising effect compared with non-iodised salt. This view is consistent with our finding in the logistic regression that iodised salt was used in cheaper rather than more expensive goods.

Please insert Table III here

Table IV highlights counterarguments against salt iodisation that seem to be important for the non-users among the processors. A clear majority (58.1%) of the non-users among the responding bakers and butchers express the view that the use of iodised salt does not provide them with an additional benefit (statement 7). A majority of respondents comment that the use of iodised salt is not wanted by customers (statement 8) and that they fear an oversupply of iodine for their customers (statement 9). Non-users of iodised salt make clear statements indicating that they do not feel responsible for the iodine status of their customers: 80% of the non-users agree with the statement that their customers should themselves decide whether and how much iodine they consume (statement 6), and 50% share the view that their customers could use tablets in case they wished to supplement their iodine intake (statement 10).

Please insert Table IV here

There is evidence in Table V that processors who do not use iodised salt are not fully informed and are also uncertain about the need for and the health benefits of salt iodisation. All statements in Table V received a 40%-or-more share of neither/nor answers on the Likert scale. This indicates that non-users among the processors are to a large extent undecided regarding two different topics: (i) the need for and the health benefits of salt iodisation; and (ii) marketing implications due to the iodisation of salt. Concerning health benefits, a large number (53%) of the non-users of iodised salt who responded neither agreed nor disagreed when asked whether the iodine status of the customers is already sufficient (statement 11). There seems to be a widespread lack of knowledge regarding the actual iodine status of the population. Moreover, more than 45% of the respondents had a neither/nor response to whether customers have allergic reactions to iodised salt (statement 13) and to whether they try to keep their list of ingredients as short as possible (statement 14). Regarding the marketing implications, there seems to be a lack of information among bakers and butchers on whether their customers would want iodised salt in processed foods or not.

Statement 12 saying that the use of iodised salt cannot be easily commercialised has a neither/nor share of 50%. Moreover, processors who do not use iodised salt seem to be somewhat undecided regarding the quality of iodised compared with sea salt, which is mostly used in organic foods. There is a neither/nor share of 40.3% of responding butchers and bakers who are undecided about statement 15 saying that they prefer sea salt for its natural iodine content.

It is striking in the empirical analysis that more butchers than bakers agree with arguments for the use of iodised salt (Table III) and fewer butchers than bakers agree with the negative statements 7 ("...does not provide us an additional benefit") and 8 ("... is not wanted by our customers") (Table IV). Both bakers and butchers seem to suffer from imperfect information on the iodine status of their customers. 55% of the respondents in both groups gave a neither/nor answer to statement 11 in Table V ("The iodine status of our customers is already sufficient").

Please insert Table V here

5 Discussion

Some important lessons can be drawn from the logistic regression and the online survey on possible reasons behind the use or non-use of salt iodisation by German food processors and on public health. Processors' behaviour and perceptions concerning iodisation are crucial to understanding the low and declining user share of iodised salt in the food groups *bread*, *meat* and *dairy*.

A first important lesson is that the limited use of iodised salt in processed foods is not caused by a price disadvantage of iodised compared with non-iodised salt (see Table II). On the contrary, iodised salt is more likely to be used in lower-priced bread and meat products. There is more of an image problem for iodised salt since its use in the food groups *bread* and *meat* is significantly lower in products which consumers perceive as high-quality products as indicated by organic certification, the use of wholegrain or, for meat products, by a manufacturer's brand rather than a store brand.

A second lesson is that processors have imperfect information about the iodine status of the population, and this might have been a barrier to a wider use of iodine fortification. Most non-users of iodised salt among the bakers and butchers in the online surveys feared an oversupply of iodine for their customers (see Table IV), whereas a whole decade ago scientific studies reported an insufficient iodine intake for about one third of the population and no indication of oversupply and studies in recent years have reported a return to an iodine-deficit status (Esche *et al.*, 2019; Arbeitskreis Jodmangel e.V., 2021). Additionally, trendy salts like sea salt are perceived by a noticeable share of processors as natural products and, therefore, as superior to iodised salt.

A third important lesson is that processors have a biased perception of consumers' views on iodised salt, and this too hindered a wider use of iodine fortification. The online survey shows that a large proportion of non-users among the processors are of the opinion that consumers do not want the use of iodised salt (see Table IV). This view is not consistent with a recent online survey of German consumers themselves about their perceptions of iodised salt (Kirchhoff and Herrmann, 2020). More than 80% of the respondents in that survey stated that they use iodised salt in the household, and most consumers perceived iodised salt as the

normal health-promoting salt. Positive views on iodised salt dominated. Furthermore, there was a clear majority of respondents (75% or more) who objected to critical statements which processors had perceived as the view of consumers. 77.9% of the respondents, for example, did not fear an oversupply of iodine due to the iodisation of salt. Herrmann *et al.* (2019), in discussing the role of regulation, have argued with the help of a market model that the processors' demand for iodine salt has been depressed by (i) the negative impact of the feedback of iodine-critical consumers on the input demand curve, and (ii) a lack of continuous information campaigns on the health benefits of using iodised salt.

We see at least three implications for policy and public health arising from the empirical evidence presented. First, it is important to address and revitalise information policies on the role of salt iodisation for public health in Germany and target both consumers and processors. Incomplete information by processors contributes to a market failure as the degree of salt iodisation of processed foods is too low from a public-health perspective. Secondly, the low salt iodisation at the processors' level implies that universal salt iodisation, as defined by the WHO (2014a), is not being realised in Germany. A fruitful approach could be to address this problem by integrating salt iodisation in the government "Reduction and Innovation Strategy". Reformulation could be targeted at both salt reduction and iodine fortification. Further steps in salt reduction could be combined with an increase of the iodine content in salt. Recent monitoring shows that "an increase of the current maximum level of iodine in salt from 25 to 30 mg per kg salt would be of no risk to health at the current level of iodised salt use in processed foods" (BfR, 2021). Thirdly, it is important for policy makers, food processors and also for health professionals to be aware of insights from the food manufacturers' practices and the bakers' and butchers' perceptions of iodised salt. Barriers to salt iodisation as well as opportunities from the increased use were visible from the empirical results.

Open questions remain for future research as well, in particular the need for comprehensive cost-benefit analyses of regulatory options for reaching the objectives of universal salt iodisation. In a market economy, there are certainly powerful arguments for the German approach to rely on voluntary rather than mandatory rules for iodine fortification and on firms making their own decisions on recipes. However, there is strong evidence, for example from the experience of the U.K.'s salt policy, that strict regulations on the supply side in respect of reformulation will influence public-health goals more effectively than consumer information policies (Gressier *et al.*, 2021; Griffith *et al.*, 2017).

6 Conclusions

There are major challenges to achieving the goal of universal salt iodisation. We showed for Germany that the use of iodised salt in the processing sector is much lower than in private households and it is declining. Marketing activities by firms promoting "natural" salt types such as sea salt have increased and have weakened the competitive position of iodised salt, whereas government information campaigns on the role of iodised salt for public health have been reduced. Our analysis indicates that the perceptions of processors to salt iodisation are also important: processors have knowledge deficits regarding the relevance of iodised salt for public health and the iodine status of the population, and they suffer from distorted information on

consumer perceptions of iodised salt. We see a potential to strengthen salt iodisation of processed foods by revitalising government information campaigns for consumers and processors and by integrating salt iodisation with salt reduction in reformulation strategies.

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Table I: Distribution of salt types across the three food groups

Number of products/percentage shares	Salted and unsalted products	Only salted products			
		<i>Bread, meat, dairy</i>	<i>Bread</i>	<i>Meat</i>	<i>Dairy</i>
Total number of products	30,345	20,723	3,850	11,487	5,386
Excluded – no information about salt additives	-435				
Statistical sample	29,910	20,723	3,850	11,487	5,386
Percentage of products with... (%)					
any salt added ^{a)}	69.3	100	100	100	100
<i>iodised</i> salt ^{b), c)}	19.7	28.5	9.5	34.2	1.6
sea salt ^{d)}	2.5	3.5	10.2	2.2	1.7
<i>non-iodised</i> salt	47.1	68.0	80.3	63.6	96.7

^{a)} Table salt, common salt, nitrite salt, sea salt, rock salt, evaporated salt, other types of salt.-

^{b)} Contains 15-25 mg iodine/kg salt.- ^{c)} Iodised sea salt (algae or iodate); n = 3.- ^{d)} Contains 0.1-2 mg iodine/kg salt.

Source: Authors' computations.

Table II: Selected estimation results of the logistic regression for *bread* and *meat*^{a)}

<i>Bread</i>			<i>Meat</i>		
Variable	Odds (SE) ^{b)}	OR ^{c)}	Variable	Odds (SE)	OR
<i>Constant</i>	0.404 (0.415)	1.498	<i>Constant</i>	0.134 (0.107)	1.144
<i>Wholegrain</i>	-0.516** (0.186)	0.597	<i>Organic</i>	-0.973*** (0.162)	0.378
<i>Private label</i>	-0.158 (0.164)	0.854	<i>Private label</i>	0.607*** (0.054)	1.835
<i>Price</i> (€/100g)	-1.600*** (0.315)	0.202	<i>Ln(Price)</i> (€/100g)	-0.971*** (0.049)	0.379
Number of salt additives (reference: <i>one salt additive</i>)					
<i>Two salt additives</i>	1.699*** (0.274)	5.470	<i>Two salt additives</i>	1.243*** (0.086)	3.467
<i>Three salt additives</i>	2.028*** (0.485)	7.601	<i>Three salt additives</i>	0.851*** (0.210)	2.343
Nagelkerkes R^2	0.386		0.179		
χ^2 –test	650.798***		1475.029***		
Classification rate	88.7%		68%		
N	2,843		10,119		

a) The coefficients of the control variables (Z) in equation (3) are not disclosed here: the location of the store, the food retailer, subcategories of each product category, large manufacturer, loose pastry (in the regression for bread). ***, [**, *]: Significantly different from zero at a level of 99.9 [99, 95] percent. b) SE: Standard deviation. c) OR: Odds ratio.

Source: Authors' computations; for full and alternative models, see Bissinger et al. (2018), Tables 7 and 8.

Table III: Reasons for the use of iodised salt in processing foods: the perception of bakers and butchers^{a)}

Statement	Group	Agreement (%)	Disagreement (%)	Neither/Nor (%)
1. We use iodised salt in order to contribute to the health of the population.	All	74.4	12.1	13.1
	Bakers	66.7	20.5	12.8
	Butchers	80.0	6.7	13.3
2. As the iodine intake is insufficient with a normal diet, we use iodised salt in our products.	All	70.7	12.1	17.2
	Bakers	56.4	17.9	25.6
	Butchers	80.0	8.3	11.7
3. Iodised salt is used as it was recommended some years ago.	All	68.7	21.2	10.1
	Bakers	64.1	25.6	10.3
	Butchers	71.7	18.3	10.0
4. We use iodised salt to do something good for our customers.	All	66.7	17.2	16.2
	Bakers	53.8	25.6	20.5
	Butchers	75.0	11.7	13.3
5. With regard to price, it does not matter whether we use iodised or non-iodised salt.	All	62.6	27.3	10.1
	Bakers	48.7	43.6	7.7
	Butchers	71.7	16.7	11.7

^{a)} The sample of bakers and butchers who use iodised salt is used: N = 99; bakers: N = 39; butchers: N = 60. Responses on the Likert Scale: 1: I strongly disagree; 2: I disagree; 3: neither/nor; 4: I agree; 5: I agree strongly. The categories Agreement (Disagreement) in this Table add up the responses under 4 and 5 (1 and 2).

Source: Authors' computations from online survey.

Table IV: Reasons for the non-use of iodised salt in processing foods: perceptions of bakers and butchers^{a)}

Statement	Group	Agreement (%)	Disagreement (%)	Neither/Nor (%)
6. Our customers themselves should decide whether and how much iodine they consume.	All	79.8	4.0	16.1
	Bakers	80.6	1.6	17.7
	Butchers	79.0	6.5	14.5
7. The use of iodised salt does not provide us with an additional benefit.	All	58.1	17.7	24.2
	Bakers	61.3	11.3	27.4
	Butchers	54.8	24.2	21.0
8. The use of iodised salt is not wanted by our customers.	All	52.4	19.4	28.2
	Bakers	58.1	11.3	30.6
	Butchers	46.8	27.4	25.8
9. We fear an oversupply of iodine for our customers.	All	50.8	31.5	17.7
	Bakers	43.5	32.3	24.2
	Butchers	58.1	30.6	11.3
10. If our customers wish to supplement iodine, they could use tablets.	All	50.0	16.9	33.1
	Bakers	53.2	16.1	30.6
	Butchers	46.8	17.7	35.5

^{a)} The sample of bakers and butchers who do not use iodised salt is used: N = 124; bakers: N = 62; butchers: N = 62. Responses on the Likert Scale: See Table III.

Source: See Table III.

Table V: Non-use of iodised salt in processing foods and imperfect information: perceptions of bakers and butchers^{a)}

Statement	Group	Neither/Nor (%)	Agreement (%)	Disagreement (%)
11. The iodine status of our customers is already sufficient.	All	53.2	36.3	10.5
	Bakers	54.8	37.1	8.1
	Butchers	54.6	35.5	12.9
12. The use of iodised salt cannot be easily commercialised well.	All	50.0	26.6	23.4
	Bakers	46.8	32.3	21.0
	Butchers	53.2	21.0	25.8
13. Our customers have allergic reactions to iodised salt.	All	47.6	22.6	29.8
	Bakers	54.8	24.2	21.0
	Butchers	40.3	21.0	38.7
14. In order to keep our lists of ingredients as short as possible.	All	46.0	32.3	21.8
	Bakers	45.2	35.5	19.4
	Butchers	46.8	29.0	24.2
15. We prefer sea salt due to its natural iodine content.	All	40.3	29.0	30.6
	Bakers	41.9	35.5	22.6
	Butchers	38.7	22.6	38.7

^{a)}The sample of bakers and butchers who do not use iodised salt is used: N = 124; bakers: N = 62; butchers: N = 62. Responses on the Likert Scale: See Table III.
Source: See Table III.