Risiken erkennen – Gesundheit schützen

Indications of the possible formation of benzene from benzoic acid in foods

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Benzene is an environmental pollutant which consumers mainly ingest via respiratory air. It can also occur as contamination in drinking water and foods. Benzene is principally emitted from petrol through exhaust gases. The substance is carcinogenic and damages germ cells. The available data do not allow the establishment of a safe level of exposure. Like all carcinogenic substances for which no toxicological threshold value can be indicated, benzene intake should be minimised and/or avoided as far as possible in line with preventive consumer protection.

There is a suspicion that small amounts of benzene may be formed from benzoic acid in non-alcoholic beverages in the presence of ascorbic acid. Benzoic acid and ascorbic acid are food additives which must be declared on the food. Benzoic acid or E 210 is a preservative which also occurs naturally, for instance, in cranberries. A maximum amount of 150 mg/l benzoic acid may be added to non-alcoholic flavoured beverages (except milk-based beverages). No maximum amount has been defined for ascorbic acid (E 300). In accordance with good manufacturing practice, only the amount may, however, be used which is necessary to achieve the desired effect ("*quantum satis*"). Ascorbic acid occurs as a natural substance (vitamin C), for instance, in many berries and fruit.

Studies on soft drinks and fruit drinks with differing levels of benzoic acid and ascorbic acid suggest that small amounts of benzene could be formed. Laboratory tests prove that under certain reaction conditions benzene is formed from benzoic acid. In this connection different factors play a role like the concentrations of the two additives, the existence of certain minerals such as copper or iron sulphate which act as catalysts in the formation of benzene, beverage pH, storage temperature and exposure to UV light. Whether and to what extent benzene is actually formed in the corresponding foods cannot, however, be reliably assessed on the basis of the data available.

In order to assess the health relevance of a possible benzene contamination of soft drinks, the latter must in any case be compared to the unavoidable contamination from other sources. With the chemical-analytical data available it is not possible to assess whether an amount of benzene is formed in soft drinks that makes a significant contribution to the total benzene intake of man and whether this constitutes an additional health risk. The Federal Institute for Risk Assessment (BfR) cannot, therefore, assess at present the possibly associated risk. The Institute has recommended asking the food control authorities of the different federal states to compile available data on benzene content as well as on the content of benzoic acid and ascorbic acid in beverages and other foods. This is currently being done.

1 Subject matter of the assessment

The Federal Institute for Risk Assessment has issued an expert opinion on whether benzene may be formed in beverages from the food additive benzoic acid in the presence of ascorbic acid.

2 Results

Benzene is considered to be carcinogenic and to cause damage to germ cells (germ cell mutagen). According to the current state of knowledge no amount can be indicated for substances of this kind which is considered safe.

Several studies, involving chemical experiments to examine the possible formation of benzene from benzoic acid in the presence of ascorbic acid, clearly show that benzene may be formed from benzoic acid under certain reaction conditions which may also exist in some beverages and other foods. Studies on beverages containing presumably different amounts of benzoic acid suggest that low amounts of benzene may be formed in beverages and other foods containing benzoic acid (and benzoates, respectively) and ascorbic acid. Whether and to what extent this actually happens in foods of this kind cannot, however, be reliably assessed on the basis of the data available.

For that reason it is not possible either to assess whether amounts of benzene can be formed in foods of this kind which make a significant contribution to total benzene intake. Consequently, it is not possible to currently assess a possibly associated health risk. This would require further chemical-analytical data. BfR, therefore, recommends to the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) that it pass on this expert opinion to the food control authorities and ask them to supply any available data on benzene levels in beverages and other foods. In this connection, data would be particularly helpful which also permit a statement on the benzoic acid and ascorbic acid levels in the corresponding foods, e.g. on the basis of the declaration of additives and ingredients or on the basis of measurement results.

3 Reasons

According to BfR research the statement that benzene can be formed from the food additives benzoic acid and ascorbic acid is based on studies conducted in the early 1990s. They sought to determine the underlying causes of benzene contamination of certain mineral waters which had come to light. At that time it was noted that other beverages contained small amounts of benzene, too. In further studies, e.g. by Gardner and Lawrence (1993) it was shown that benzene can be formed from benzoic acid in the presence of ascorbic acid and transition metal ions like copper(II) and iron(III). The chemical reaction is catalysed by the metal ions which occur in low concentrations in drinking water, too.

3.1 Risk assessment

3.1.1 Agent

The food additives, benzoic acid (E 210) and sodium benzoate, potassium benzoate and calcium benzoate (E 211 – E 213), are authorised for certain foods, including e.g. non-alcoholic, flavoured beverages (except dairy-based beverages) up to a maximum level of 150 mg/l. Ascorbic acid (E 300) is generally authorised *quantum satis* for foods (except for certain foods). The combination of benzoic acid and ascorbic acid is, therefore, admissible for certain food categories like non-alcoholic, flavoured beverages (except dairy-based beverages).

For benzene a draft EU Risk Assessment Report was prepared within the framework of assessment in accordance with Council Regulation (EEC) No. 793/93 on the evaluation and control of the risks of existing substances of 23 March 1993 with major contributions by BfR (Germany is the rapporteur). The Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) commented in February 2003 on the "environment" part and in November 2003 on the "human health part" (CSTEE 2003a, 2003b). A final risk assessment report has not yet been published.

3.1.2 Hazard

Benzene is considered to be carcinogenic and to cause damage to germ cells (germ cell mutagen). The available data do not allow the establishment of a safe level of exposure (CSTEE 2003).

3.1.3 Exposure

Some studies examined the possible formation of benzene from benzoic acid and ascorbic acid in experimental reaction batches to which components had been added. In some cases, the benzene content in foods was measured, too.

3.1.3.1 Investigation of the formation of benzene in experimental reaction batches

In a study by Gardner and Lawrence (1993) the formation of benzene was examined. According to information provided by the authors, the concentrations of the reactants were adjusted to the conditions in foods (e.g. 6.25 mmol/l sodium benzoate and 8 mmol/l ascorbate). In a typical reaction batch for this study the benzene concentration increased during the first 10 minutes and remained more or less steady during the subsequent 30 minutes. During further investigations the benzene concentration was, therefore, determined after a reaction time of 15 minutes at 25 °C. The benzene levels measured were lower than 50 nmol/l and < 1 ppb, respectively (please note: 50 nmol/l benzene is equivalent to 3.9 µg/l and 1 ppb equivalent to 1 µg/kg). The detection limit for benzene was approximately 1 nmol/l. In a reaction batch containing 6.25 mmol/l sodium benzoate, the benzene concentration correlated positively with the concentration of the added ascorbate up to an ascorbate concentration of approximately 8 mmol/l. At higher ascorbate concentrations the benzene concentration correlated negatively with the concentration of the added ascorbate. The pH-dependency of the reaction was measured across pH values from 2 – 7. At pH 2 the benzene formation reached a maximum (approximately 37 nmol/l); at higher pH values significantly less benzene was formed. Moreover, an association between the amount of benzene formed and the concentration of copper sulphate (0.05 - 4 mmol/l) and iron sulphate (0.05 – 1 mmol/l) added was examined. The highest level of benzene was reached at 1 mmol/l copper sulphate and 0.05 mmol/l iron sulphate respectively.

In a study by McNeal *et al.* (1993) an aqueous solution containing 0.04 % sodium or potassium benzoate (this is equivalent to 2.8 mmol/l sodium benzoate and 2.5 mmol/l potassium benzoate, respectively) and 0.025 % ascorbic acid (this is equivalent to 1.4 mmol/l), was examined. According to the authors this corresponds to the usual concentrations in beverages. Part of the solution was exposed to UV light, another part was heated to 45 °C and a third part was stored in the dark at ambient temperature. After 20 h UV eradiation and heating to 45 °C, respectively, approximately 300 µg benzene/kg were formed in each case. Four µg benzene/kg were formed in the solution stored in the dark at ambient temperature. After 8 days the benzene content in the solution stored at ambient temperature had increased to 266 µg/kg whereas the benzene contents in the heated and UV eradiated solutions remained steady.

In a study by Chang and Ku (1993) results similar to those of the above-mentioned studies were observed. This publication cannot be evaluated in detail because the text is written in Asian fonts but the English abstract and the English captions of the figures show that after 8 days reaction time benzene contents of up to 200 µg/kg were measured and that, for varying ascorbate and/or benzoate concentrations, a reaction optimum was observed for certain concentrations in each case.

3.1.3.2 Measurement of benzene in foods

In the study by McNeal *et al*. (1993) foods were examined, too. In foods (including some non-alcoholic beverages) containing benzoic acid and ascorbic acid naturally, benzene levels of ≤ 1 µg/kg were detected. In foods to which benzoate and ascorbic acid had been added, benzene levels in a range of < 1 to 38 µg/kg were measured; in non-alcoholic beverages the levels were ≤ 2 µg/kg. In foods which allegedly contain benzene according to some older publications, benzene levels of ≤ 2 µg/kg were measured in the study by McNeal *et al*. (1993). The authors assume that the higher benzene levels described in the older publications are attributable to laboratory-related contamination.

In a study by Page *et al*. (1992) carbonated non-alcoholic beverages and fruit drinks were examined. A detection limit for benzene of 0.02 µg/kg was stated. In 20 carbonated non-alcoholic beverages on whose packaging a benzoate additive was declared, the benzene levels ranged between 0.013 and 3.8 µg/kg (mean value 0.79 µg/kg), whilst for six corresponding beverages on which a benzoate additive was not declared the benzene contents levels were between 0.029 and 0.12 µg/kg (mean value 0.062 µg/kg). For 16 fruit drinks which were produced from cranberries (with natural benzoic acid content) and on whose packaging no benzoate was declared, the benzene levels ranged between 0.011 and 1.8 µg/kg (mean value 0.29 µg/kg) and for 13 other fruit drinks which were produced without cranberries they ranged between 0.011 and 0.66 µg/kg (mean value 0.12 µg/kg). The authors report that based on further experiments (which are not, however, described in more detail) laboratory-related benzene contamination was minimal. Although production-related benzene contamination of foods cannot be completely ruled out, the results of this study suggest that benzene can be formed in beverages from benzoic acid.

In a study in which numerous different foods were examined for the occurrence of volatile organic compounds, benzene was found in three Cola beverages (whereby it is not clear how many Cola beverages were examined overall). The benzene levels measured in Cola beverages ranged between 1 and 138 µg/kg (Fleming-Jones and Smith 2003). It is not clear whether benzene was formed in these cases from benzoic acid or reached the beverages as a contaminant during production. In principle, it must also be considered whether any contamination may have occurred during chemical analysis.

3.1.3.3 Benzene exposure from other sources

The amount of benzene unavoidably ingested from respiratory air and the consumption of drinking water and foods, in which it occurs as a contamination and/or pollutant, can vary. However, it is frequently of an order of magnitude of some hundred µg per person and day (CSTEE 2003; Ramsay 1994). According to the draft EU Risk Assessment Report on Benzene (Environment Part, Draft of 13 May 2002, p. 137) respiratory air makes the highest contribution (between 96 and more than 99%) to total benzene intake whereas drinking water and foods only make a minor contribution. In this connection the possible formation of benzene from benzoic acid and ascorbic acid was obviously not taken into account. If the above-mentioned data on the amount of benzene that can be formed from benzoic acid and ascorbic acid were confirmed, then BfR will, if necessary, make sure this is taken into account in an appropriate manner in the EU Risk Assessment Report.

The Drinking Water Regulation specifies a limit value of 1 µg/l for benzene.

3.1.4 Risk characterisation

Benzene is considered to be carcinogenic and to cause damage to germ cells (germ cell mutagen). The available data do not allow the establishment of a safe level of exposure.

In model experiments during which the reaction conditions were varied, it was shown that the formation of benzene from benzoic acid in the presence of ascorbic acid and transition metal ions can obviously be influenced by several factors. These include concentrations of benzoic acid, ascorbic acid and the transition metal ions which act as catalysts, pH, temperature, UV exposure as well as reaction duration. The described studies clearly show that benzene can be formed under certain reaction conditions in concentrations up to several hundred micrograms per kilogram. There may also be comparable reaction conditions in some beverages and other foods. Whether and to what extent this actually occurs in such foods cannot, however, be reliably assessed on the basis of the available data.

In the study by McNeal et al. (1993) maximum benzene concentrations of 2 µg/kg were measured in non-alcoholic beverages. In the study by Page et al. (1992) the mean values of the benzene levels in beverages was less than 1 µg/kg, the maximum value was 3.8 µg/kg. This suggests that the benzene amount, which can be ingested from beverages in which benzene is formed at the above concentrations, would be considerably less than the benzene amount ingested from respiratory air and the consumption of drinking water and foods in which benzene may occur as contamination and/or as an environmental pollutant. However, the data from the studies quoted cannot be considered as representative.

In the study by Page et al. (1992) the benzene levels in the beverages on whose package a benzoate content was declared were approximately ten times higher than in beverages which bore no such declaration. However, the benzoate content was not measured. Consequently, it cannot be reliably assessed whether the benzene amount formed in these cases correlated with the benzoate amount.

It is not clear whether the benzene found in Cola beverages in a concentration of up to 138 µg/kg was formed from benzoic acid or must be seen as a production-related or laboratory related contamination.

Overall, it cannot be reliably assessed on the basis of the data available whether benzene in foods is formed from benzoic acid in the presence of ascorbic acid in amounts which make a significant contribution to total benzene intake. Consequently, the possibly associated health risk cannot be assessed at present.

4 Action framework/measures

It is advisable to minimise and/or avoid the intake of benzene as far as possible. This is the standard practice for substances which are to be considered as carcinogens and germ cell mutagens.

However, further chemical-analytical data are needed in order to assess the possible risk from simultaneous use of benzoic acid and ascorbic acid in foods. If it turned out that the simultaneous use of benzoic acid and ascorbic acid in foods makes a significant contribution to total benzene intake, it may be necessary to check whether the authorisation framework for a simultaneous use of benzoic acid and ascorbic acid in foods would have to be changed.

BfR has, therefore, recommended to the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) that it pass on this expert opinion to the food control authorities and ask them to supply any available data on the benzene content in beverages and other foods. In this connection data would be particularly helpful which also permit a statement on benzoic acid and ascorbic acid levels in the corresponding foods e.g. on the basis of the declaration of the additives and ingredients or on the basis of measurement results.

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