Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

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Impact on health when sugar is replaced with intense sweeteners in soft drinks, 'saft' and nectar

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Preface

In 2004, the Norwegian Food Safety Authority (Mattilsynet) asked the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) to carry out an assessment of the health impact if consumers substitute sugar sweetened soft drinks, 'saft' and nectar with the intense sweetened alternatives.

***Ad hoc* group**

Under the auspices of VKM, an *ad hoc* group comprised of VKM members and external experts has prepared this report. The members of the *ad hoc* group have been Professor Lene Frost Andersen, PhD (Chair), Senior scientist Trine Husøy, PhD, Henrik Nøtvik Jakobsen, Cand. odont and Professor Svein Olav Kolset, PhD.

Jannicke Fredriksen (Master in Clinical Nutrition) and Tone Kristin Omsland (Master in Clinical Nutrition) both from the University of Oslo have contributed with literature and background material regarding overweight and diabetes and consumption of sugar sweetened soft drinks in chapter 6. Christina Bergsten and Ingvild Kristine Tømmerberg from the Norwegian Food Safety Authority have contributed with intake estimates for the intense sweeteners and benzoic acid and added sugar, method description for these estimates and definition of soft drinks, 'saft' and nectar in the legislation.

Two of VKM's scientific panels have reviewed the report during its preparation, and the members of the VKM Scientific Steering Committee have given their final assessment and approval. The report has been submitted to and discussed in the National Council of Nutrition (Nasjonalt råd for ernæring).

Panel on food additives, flavourings, processing aids, materials in contact with food and cosmetics

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The report was approved by the members of the VKM Scientific Steering Committee of the Norwegian Scientific Committee for Food Safety (VKM) on 1 February 2007.

Coordinators in the VKM Secretariat have been Bente Mangschou and Tor Øystein Fotland.

Acknowledgement

VKM wishes to thank Alix Young Vik (Associate Professor), Faculty of Odontology, University of Oslo for her contribution regarding dental health in this report, and Ragnhild Halvorsen (MD PhD) for her contribution to the section on benzoic acid and hypersensitivity.

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1 Summary

1.1 Background

National representative dietary surveys among children and adolescents from the 1998-2001 revealed that one of the most important health-related problems in the diet of children and adolescents was a high intake of added sugar, and the major source of added sugar was soft drinks and 'saft' ('saft' is a fruit concentrate and shall be mixed with water before drinking).

In 2003, a WHO Technical report "Diet, Nutrition and Prevention of Chronic Diseases" concluded that sugar sweetened drinks probably increased the risk of overweight. The Norwegian Directorate for Health and Social Affairs (Sosial- og helsedirektoratet) recommends a reduction in consumption of sugar sweetened soft drinks. A higher consumption of soft drinks with intense sweeteners might be the result of such a recommendation. The consequences of a high intake of intense sweeteners and benzoic acid have to be explored as regards possible exceedances of the ADI.

The Norwegian Food Safety Authority requested the Norwegian Scientific Committee for Food Safety (VKM) to assess the relationship between consumption of sugared soft drinks, 'saft' and nectar and health challenges such as overweight, diabetes and dental health on one hand, and the potential public health risks of elevated intake of intense sweeteners and benzoic acid on the other. The level of benzoic acid might potentially be higher in soft drinks, 'saft' and nectar with intense sweeteners since sugar, which has a preservative effect, is removed. VKM was requested to evaluate exposure levels (current situation) from existing national dietary surveys and scenarios where it was assumed that 50% of the consumed soft drinks, 'saft' and nectar contain added sugar, and 50% contain intense sweeteners (the 50% scenario) and finally exposure levels where it was assumed that all of the consumed soft drinks, 'saft', and nectar contain intense sweeteners (the 100% scenario).

This report does not discuss other health problems beside overweight, diabetes and dental health which may be related to high consumption of sugared soft drinks, 'saft' and nectar, such as poor nutrient quality of the diet in relationship to coronary heart diseases and cancer.

1.2 Results and conclusions

Trends in the consumption of sugar, intense sweeteners, soft drinks and 'saft'
Both the food consumption surveys made by Statistics Norway from 1975 to 2004 and national representative dietary surveys conducted in the period 1993-2001 show that the consumption of added sugar and sugared soft drinks and 'saft' has increased over the last decades. According to sales figures for carbonated soft drinks after 2002 the consumption pattern seems to be changing as the sales of soda with intense sweeteners and water are increasing, while the sales of sugar sweetened soda are decreasing. The sales figures for carbonated soft drinks (both with sugar and intense sweeteners) also show a small decrease from 2002 to 2006. It remains to be seen whether this is an enduring trend, and if so, in what age groups these changes have occurred.

Effects of sugar/intense sweeteners from soft drinks/'saft' on overweight and diabetes
Five out of 9 prospective studies and 4 out of 4 intervention studies showed a positive association between high consumption of sugar sweetened soft drinks and weight gain/obesity. In conclusion, epidemiological and experimental evidence indicate that an increase in the consumption of sugar sweetened soft drinks is associated with weight gain and obesity. The majority of the

published studies on intense sweeteners and body weight indicate that intense sweeteners do not lead to an increase in the energy intake and body weight.

There are few studies on the association between consumption of sugar sweetened beverages and the risk of developing diabetes, especially diabetes type 1. The few prospective studies available indicate a positive correlation between sugar sweetened beverage consumption and the risk of developing diabetes type 2. However, this may result from the increased risk of weight gain and obesity observed with high consumption of sugar sweetened beverages, and may not necessarily be a direct effect of the sugar sweetened beverages.

The epidemiological data generating the background for the conclusions on health effects (overweight and diabetes) from soft drinks, all have their limitations including methodological aspects such as small sample sizes, short duration of follow-up, lack of repeated measures in dietary exposures and outcomes, and confounding by other dietary and lifestyle related factors. These limitations are discussed throughout the report. More studies on the association between soft drink consumption and overweight and diabetes are needed to confirm the conclusions. Especially research related to the consumption of sugar sweetened soft drinks and diabetes, both type 1 and type 2 is scarce.

Sugar/intense sweeteners from soft drinks, 'saft' and nectar and dental health
Sugar sweetened soft drinks, 'saft' and nectar can affect dental health in two ways: through dental caries and dental erosion. The association between sugar intake and dental caries is well documented and relatively linear. Individuals with good oral hygiene and regular fluoride exposure may tolerate higher levels of sugar intake before caries occurs. As there are no differences in pH and acid content between sugar sweetened soft drinks, 'saft' and nectar and the drinks with intense sweeteners, a reduction of the sugar content will not affect the incidence of dental erosion, but most probably reduce the incidence of caries. From a dental health aspect it is recommended to reduce the intake of acidic and sugar sweetened drinks.

Dietary surveys used in the exposure assessment
The dietary surveys used in the exposure assessments of soft drinks 'saft' and nectar and the intake estimates of added sugar, intense sweeteners and benzoic acid were conducted between 1997 and 2001, and may therefore not be fully representative for the current situation. In addition, no intake data for intense sweeteners from other sources than soft drinks, 'saft' and nectar were available for children.

Risk characterisation of intake of added sugar
The current intake estimations show that the mean percentage of energy (E%) deriving from added sugar is higher than recommended among Norwegian children and adolescents, while the intake among adults is around the maximum recommended level of 10E%. About 85% of the 4-, 9- and 13-year-olds had more energy from added sugar than 10E%. Among the 1- and 2-year-olds the proportions were 43% and 56%, respectively.

In the scenario where it is assumed that 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners and the other half contains added sugar, the estimated mean percentage of energy from added sugar is below or close to 10E% among both 1- and 2-year-olds and adults. However, 76-84% of the older children (4- to13 years of age) still have an energy percentage from added sugar higher than 10E%.

In the scenario where it is assumed that 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners, the mean percentage of energy from added sugar is estimated to be below or close to 10E% for all age groups. A change from the current level to the 100% scenario reduced considerably the percentage of children with E% from added sugar above the maximum recommended intake of 10E%. However, about 50% of the children aged 4- to13 years still have

an energy percentage from added sugar higher than 10E%, while the proportions among 1- and 2- year-olds are 25% and 17%, respectively.

Risk characterisation of intense sweeteners and benzoic acid
It was not reported any use of neohesperidin DC and thaumatin in soft drinks, 'saft' and nectar by the industry, and no risk assessment was performed for these intense sweeteners.

The estimated intakes of the intense sweeteners aspartame, saccharin and cyclamate from soft drinks, 'saft' and nectar were well below the acceptable daily intake (ADI) for all age groups both at the current level of intake and in the 50% and 100% scenarios. It was not possible to estimate the intake of sucralose because sucralose first was introduced to the Norwegian market in 2005. At the present use, it is anticipated that the intake of sucralose is well below ADI for all age groups. Altogether, no health concern is connected to the use of the above-mentioned intense sweeteners in soft drinks, 'saft' and nectar.

The estimated intake of acesulfame K among high consumers of soft drinks, 'saft' and nectar in the age group 1-year-old children at the current level, was close to ADI, while the intake for the other age groups was well below ADI. The intake of acesulfame K was also below ADI for all other age groups when shifting from the current level to the 100% scenario. The probability of exceeding ADI for acesulfame K increased in the 100% scenario for high consumers (95th percentile) of the age groups 1- and 2-year-old children. This would represent an erosion of the safety margin for acesulfame K exposure, and the contribution from other food sources to the total intake of acesulfame K is not known.

At the current level, the estimated total intake of benzoic acid was close to ADI among high consumers (95th percentile) of soft drinks, 'saft' and nectar in all groups except men, and above ADI among the high consumers among 1-year-old children. In the 100% scenario the total benzoic acid intake from food was above ADI among high consumers in all groups except men. Children (95th percentile) from 1- to 4-years of age were found to have the highest intake of benzoic acid on a body weight basis. The estimated total benzoic acid intake from food does not include the intake of benzyl derivatives used as flavourings in food, and which are metabolised to benzoic acid in the body. In addition to the exposure from food, both adults and children might be exposed to a considerable amount of benzoic acid from cosmetics.

Adverse health effects of a high benzoic acid intake are anticipated to be of most concern for children. Benzoic acid is conjugated in the body with the amino acid glycine before excretion, and the glycine capacity might be exceeded during very high intakes of benzoic acid. This is mainly a concern for organisms in growth, such as children, where absence of glycine might lead to reduced weight gain. The capacity of glycine conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein. The total benzoic acid exposure to children is not known, and the estimated high intake of benzoic acid from foods and drinks in 1- to 4-year-old children in Norway should therefore be of special concern.

1.3 Recommendations

The Norwegian Scientific Committee for Food Safety recommends:

- More up to date and detailed dietary surveys including brand-names should be performed in Norway for different age/population groups.

- More research on the association between added sugar and health is needed, especially regarding diabetes type 2.

- The estimated intake of acesulfame K approached ADI for small children and the contribution from other food sources than soft drinks, 'saft' and nectar is not known. VKM therefore recommends that the intake of acesulfame K for young children should be closely monitored in the future.

- The children from 1- to 4-years of age were found to have the highest estimated intakes of benzoic acid relative to their body weight, and their intakes exceeded the ADI. The contribution from benzyl derivates used as flavourings in food, and which are metabolised to benzoic acid in the body as well as exposure to benzoic acid from cosmetics are not included in the estimates. VKM therefore recommends that more detailed intake studies are performed where all sources of benzoic acid exposure is included.

Norsk sammendrag

1.1 Bakgrunn

Nasjonale kostholdsundersøkelser blant barn og unge på slutten av 1990-tallet og begynnelsen av 2000-tallet viser at et av de viktigste helserelaterte problemene ved kostholdet til barn og unge er et høyt inntak av tilsatt sukker. Den viktigste kilden til tilsatt sukker er sukrede leskedrikker som brus og saft. I rapporten "Diet, Nutrition and Prevention of Chronic Diseases" fra 2003 konkluderte WHO med at sukrede drikker sannsynligvis øker risikoen for overvekt. Sosial- og helsedirektoratet anbefaler redusert inntak av sukrede drikker, og en slik anbefaling vil kunne medføre et høyere inntak av drikker med intense (kunstige) søtstoffer. Konsekvensene av et økt inntak av intense søtstoffer og konserveringsmidlet benzosyre må imidlertid utredes med hensyn til mulige overskridelser av akseptable inntaksnivåer.

Mattilsynet ba derfor Vitenskapskomiteen for Mattrygghet (VKM) om å vurdere sammenhengen mellom den norske befolkningens inntak av sukrede drikker som brus, saft og nektar og helsemessige utfordringer som overvekt, diabetes og tannhelse på den ene siden og mulig helserisiko forbundet med et økt inntak av intense søtstoffer og benzosyre på den andre siden. Mengden av benzosyre kan potensielt være høyere i kunstig søtet drikke fordi sukker, som har en konserverende effekt, fjernes. I oppdraget fra Mattilsynet blir VKM bedt om å vurdere inntaksberegninger fra nasjonale landsrepresentative kostholdsundersøkelser (dagens situasjon). I tillegg ble VKM bedt om å vurdere tenkte estimater der det er antatt at 50% av all brus, saft og nektar er tilsatt sukker og 50% tilsatt intense søtstoffer (50% scenariet), samt tenkte estimater der det er antatt at alt tilsatt sukker i brus, saft og nektar er erstattet med intense søtstoffer (100% scenariet).

Utover overvekt, diabetes og tannhelse, drøfter ikke denne rapporten andre helseproblemer som kan være knyttet til et høyt inntak av sukrede leskedrikker – som for eksempel lav næringsstofftetthet, hjerte- og karsykdommer og kreft.

1.2 Resultater og konklusjoner

Inntak av sukker, intense søtstoffer, brus og saft – utvikling over tid
Både forbruksundersøkelser fra Statistisk sentralbyrå fra 1975 til 2004 og nasjonale kostholdsundersøkelser utført i perioden 1993-2001 viser at inntaket av tilsatt sukker og sukrede leskedrikker har økt de siste tiårene. Salgstall for brus etter 2002 indikerer at inntaksmønsteret er i endring, og at salget av brus med intense søtstoffer og vann øker, mens salget av sukret brus avtar. Det har vært en liten nedgang i salgstallet for kullsyreholdige leskedrikker (både sukrede og kunstig søtede) fra 2002 til 2006, men det gjenstår å se om dette er en varig trend, og hvilke aldersgrupper i befolkningen som har endret forbruksmønsteret.

Sukker/intense søtstoffer fra brus/saft og overvekt og diabetes
Fem av 9 prospektive studier og 4 av 4 intervensjonsstudier viste en positiv sammenheng mellom høyt inntak av sukrede leskedrikker og vektøkning/fedme. Resultater fra epidemiologiske og eksperimentelle studier tyder på at et økt inntak av sukrede leskedrikker er assosiert med vektøkning og fedme. Resultater fra de fleste av de publiserte studiene som omhandler sammenhengen mellom intense søtstoffer og vekt tyder på at inntak av intense søtstoffer ikke medfører økt energiinntak eller vektøkning.

Det er få studier som omhandler sammenhengen mellom inntaket av sukrede drikker og risikoen for å utvikle diabetes, spesielt type 1. De få publiserte prospektive studiene som finnes, tyder på

at det er en positiv sammenheng mellom inntaket av sukrede drikker og risikoen for å utvikle diabetes type 2. Dette kan imidlertid være et resultat av økt risiko for vektøkning og fedme, forårsaket av et høyt konsum av sukrede drikker, og behøver ikke nødvendigvis være en direkte effekt av sukrede drikker som sådan.

De epidemiologiske dataene som danner grunnlaget for de helsemessige konklusjonene om sammenhenger mellom inntaket av sukrede leskedrikker og overvekt og diabetes har noen metodiske begrensninger. Dette dreier seg blant annet om små utvalgsstørrelser, kort varighet på intervensjons- og oppfølgingsstudier, mangelfulle gjentatte målinger for kostinntak og resultater og konfunderende faktorer som andre kost- og livsstilsfaktorer. Disse begrensningene er grundig drøftet i rapporten.

Det er behov for flere studier som bekrefter de ovenstående konklusjonene, men spesielt er den forskningen som er knyttet til sammenhengen mellom inntak av sukrede leskedrikker og diabetes (både type 1 og type 2) mangelfull.

Sukker/intense søtstoffer fra brus, saft og nektar og tannhelse
Brus, saft og nektar med tilsatt sukker kan påvirke tannhelsen på to måter: I form av karies og gjennom erosjonsskader. Sammenhengen mellom sukkerinntak og karies er godt dokumentert og relativt lineær. Individer med god tannhygiene og regelmessig bruk av fluor vil kunne tolerere et høyere inntak av sukker før karies utvikles. Det er ingen forskjell i pH eller syreinnhold i sukret brus, saft og nektar og brus, saft og nektar med intense søtstoffer. Brus, saft og nektar med intense søtstoffer vil derfor mest sannsynlig føre til lavere forekomst av karies, men ingen reduksjon i forekomst av erosjonsskader. For å bedre tannhelsen anbefales det sterkt å redusere inntaket av både sukrede og syreholdige drikker.

Kostholdsundersøkelsene som er benyttet i inntaksberegningene
Kostholdsundersøkelsene som er benyttet i beregningene av inntaket av sukker, intense søtstoffer og benzosyre fra brus, saft og nektar er utført mellom 1997 og 2001, og er derfor sannsynligvis ikke helt representative for dagens situasjon. Når det gjelder inntaksberegninger for intense søtstoffer for barn, finnes det ikke tilgjengelige data for inntak fra andre kilder enn brus, saft og nektar.

Risikokarakterisering av inntak av tilsatt sukker
Inntaksberegningene viser at prosentandelen av energi som kommer fra tilsatt sukker gjennomsnittlig er høyere enn anbefalt blant barn og unge i Norge (dagens situasjon), mens tilsvarende prosentandel for voksne ligger rundt det som maksimalt anbefales på 10 energiprosent (10E%). Omtrent 85% av 4-, 9-, og 13-åringer hadde en høyere andel av energi fra tilsatt sukker enn 10E%. Henholdsvis 43% og 56% av 1- og 2-åringene hadde en høyere andel av energi fra tilsatt sukker enn 10E%.

I beregninger fra scenariet der det er antatt at 50% av all brus, saft og nektar er søtet med intense søtstoffer og den andre halvparten er tilsatt sukker (50% scenariet), er energiprosenten fra tilsatt sukker gjennomsnittlig lavere enn, eller omtrentlig 10E% blant 1- og 2-åringene og hos voksne. Mellom 76-84% av barn og unge i alderen 4-13 år har imidlertid fremdeles en beregnet energiprosent fra tilsatt sukker over 10E% i dette scenariet.

I beregninger fra scenariet der det er antatt at 100% av all brus, saft og nektar inneholder intense søtstoffer (100% scenariet) er energiprosenten fra tilsatt sukker gjennomsnittlig under eller rundt 10E% for alle aldersgruppene. En endring i forbruksmønster fra dagens situasjon til 100% scenariet, vil gi en betydelig reduksjon i andelen barn og unge med en energiprosent fra tilsatt sukker over den maksimale anbefalingen på 10E%. Likevel vil omtrent halvparten av barna i alderen 4-13 år fremdeles ha en energiprosent fra tilsatt sukker som overstiger 10E%, og blant 1- og 2-åringene vil henholdsvis 25% og 17% av barna fremdeles ha en energiprosent fra tilsatt sukker over 10E%.

Risikokarakterisering av intense søtstoffer og benzosyre
Det ble ikke rapportert bruk av neohesperidin DC eller thaumatin i brus, saft og nektar, og det har derfor ikke blitt utført noen risikovurderinger av disse søtstoffene.
Inntaket av de intense søtstoffene aspartam, sakkarin og cyklamat fra brus, saft og nektar er under det akseptable daglige inntaket (ADI) for alle aldersgrupper både i dagens situasjon, og i 50%- og 100% scenariene. Det har ikke vært mulig å beregne inntaket av sukralose i Norge, ettersom sukralose først kom på det norske markedet i 2005. Det antas at inntaket av sukralose ved dagens konsum vil være godt under ADI for alle aldersgrupper. Alt i alt synes ikke bruk av søtstoffene aspartam, sakkarin, cyklamat og sukralose i brus, saft og nektar å gi grunnlag for helsemessige bekymringer.

Det beregnete inntaket av acesulfam K fra brus, saft og nektar blant høykonsumenter (95-persentilen) i aldersgruppen 1 år gamle barn nærmer seg ADI i dagens situasjon. Inntaket i dagens situasjon for de andre aldersgruppene er godt under ADI. En endring i forbruksmønster fra dagens situasjon til 100% scenariet, øker sannsynligheten for at høykonsumenter av brus, saft og nektar blant 1- og 2-åringer kan få et inntak av acesulfam K som overstiger ADI. En slik overskridelse av ADI vil kunne representere en reduksjon av sikkerhetsmarginen for acesulfam K-eksponering. Bidraget fra andre kilder til det totale inntaket av acesulfam K er ikke kjent. De andre aldersgruppene hadde et estimert inntak av acesulfam K under ADI også i 100% scenariet.

I inntaksberegningene for benzosyre er det også inkludert bidrag fra andre matvarer enn brus, saft og nektar. Det estimerte totale inntaket av benzosyre i dagens situasjon er nært opp til ADI blant høykonsumenter (95-persentilen) av brus, saft og nektar i alle aldersgrupper unntatt menn. For 1-åringer er inntaket over ADI. Estimater for 100% scenariet viser at dersom all brus, saft og nektar var søtet med intense søtstoffer, så ville inntaket av benzosyre i mat og drikke overstige ADI for høykonsumentene i alle aldersgrupper med unntak av voksne menn. Høykonsumenter blant barn i alderen 1-4 år ville ha det høyeste inntaket i forhold til kroppsvekten. Inntaksberegningene for benzosyre inkluderer ikke inntak av benzylderivater som benyttes som aroma i næringsmidler og som metaboliseres til benzosyre i kroppen. I tillegg til inntak fra mat og drikke, vil både barn/unge og voksne kunne bli eksponert for en betydelig mengde benzosyre fra kosmetiske produkter.

Negative helseeffekter som skyldes et høyt inntak av benzosyre antas å være av størst betydning for barn. I kroppen bindes benzosyre til aminosyren glysin før utskillelse, og tilgjengelig glysin fra mat og nysyntese vil kunne overskrides ved et høyt inntak av benzosyre. Dette vil primært være av betydning for barn i vekst. Kapasiteten for glysinkonjugering hos barn er ikke kjent, men vil sannsynligvis være avhengig av ernæringsstatus og inntak av glysin fra kosten. Norske barn har i gjennomsnitt et tilstrekkelig inntak av protein. Den totale benzosyreeksponeringen hos barn er ikke kjent, og det høye inntaket av benzosyre fra mat og drikke blant norske barn i alderen 1-4 år er derfor bekymringsfullt.

1.3 Anbefalinger

Vitenskapskomiteen for mattrygghet anbefaler:

- Det bør utføres nye og mer detaljerte kostholdsundersøkelser som inkluderer merkenavn for ulike alders-/befolkningsgrupper i Norge.

- Det er behov for flere studier som ser på sammenhengen mellom tilsatt sukker og helse, spesielt med tanke på diabetes type 2.

- Det beregnete inntaket av acesulfam K nærmer seg ADI for de minste barna, og da er inntaket fra andre kilder enn brus, saft og nektar ikke inkludert i beregningene. VKM anbefaler derfor at inntaket av acesulfam K hos små barn overvåkes nøye framover.

- I henhold til beregningene har barn i alderen 1-4 år det høyeste inntaket av benzosyre i forhold til kroppsvekten. Inntaket i disse aldersgruppene overskrider ADI. Bidrag fra benzylderivater og benzosyre fra kosmetiske produkter er ikke inkludert i inntaksberegningene. VKM anbefaler derfor at det utføres mer detaljerte eksponeringsstudier der alle kilder til benzosyre inkluderes.

2 Introduction

In the course of year 2000-2001 a nationwide dietary survey among 4-, 9- and 13-year-olds (Ungkost 2000) was carried out in Norway (Pollestad *et al.*, 2002, Øverby and Andersen, 2002). Ungkost 2000 revealed that one of the most important health-related problems in the diet of children and adolescents was a high intake of added sugar, and the major sources of added sugar were soft drinks and 'saft'[1]. A high intake of sugar was also observed in surveys among 1-year-olds (Lande and Andersen, 2005a) and 2-year-olds (Lande and Andersen, 2005b). In 2003 a WHO Technical report "Diet, Nutrition and Prevention of Chronic Diseases" (WHO, 2003) concluded that sugar sweetened drinks probably increases the risk of overweight. The Norwegian Directorate for Health and Social Affairs recommends a reduction of consumption of sugar sweetened soft drinks. A higher consumption of soft drinks with intense sweeteners might be the result of such a recommendation.

High intakes of intense sweeteners and benzoic acid are considered as the possible health hazards of greatest concern if sugared drinks are replaced by "so-called" light varieties.

The intake of intense sweeteners in the adult population has been estimated in Norway in 1993 (Bergsten, 1993) and 1998 (Bergsten, 1998). The results from the 1998 survey showed that the average and the high (95th percentile) intake of intense sweeteners were well below the ADI for each sweetener. The intake of benzoic acid was estimated for adolescents (13-year-old) and adults in 2000. The high (95th percentile) daily intake of benzoic acid among 13-year-olds corresponded to 94 percent of ADI. The main contributors to the intake of benzoic acid were beverages (Bergsten, 2000).

In order to collect data to conduct this assessment, The Norwegian Food Safety Authority sent out a questionnaire to all manufacturers and importers of drinks in Norway. Data on the content of benzoic acid, aspartame, acesulfame K, cyclamate, saccharine and sugar as well as data on pH, type of acid in soft drinks, 'saft' and nectar and sales figures from 2004 were obtained.

There are some limitations connected to the data used in this risk assessment. The consumption data from the dietary surveys used in the present report have their limitations due to methodological aspects like under- and overreporting and the methods do not collect data on brand-name level. Moreover, the consumption data and the concentration data from the manufacturers are not collected in the same period of time.

This report from VKM is confined to look at the association between consumption of sugared soft drinks, 'saft' and nectar and health challenges such as overweight, diabetes and dental health on one hand and the potential public health risks of elevated intakes of intense sweeteners and benzoic acid on the other. The report will not discuss other health problems beside overweight, diabetes and dental health which may be related to high consumption of sugared soft drinks, 'saft' and nectar such as poor nutrient quality of the diet, coronary heart diseases and cancer.

1 Definition of 'saft' is given in Chapter 4

3 Terms of reference

The Norwegian Food Safety Authority has requested VKM to assess the health impact of using intense sweeteners instead of sugar in soft drinks, 'saft' and nectar[2] for vulnerable groups and the ordinary consumer.

The assessment should cover:

1. The impact on consumer health from sugar intake through soft drinks, 'saft' and nectar focusing mainly on overweight and diabetes.
2. The impact on consumer health if 50% of the consumption of soft drinks, 'saft' and nectar contain intense sweeteners and 50% contain sugar, including:
    - Do intense sweeteners affect the production of insulin in the body, and how will this affect the consumer?
    - What will the effect be on the total intake of intense sweeteners and the preservative benzoic acid if intense sweeteners replace sugar in 50% of all soft drinks, 'saft' and nectar?
    - How will dental health be affected if intense sweeteners replace sugar in 50% of all soft drinks, 'saft' and nectar?
3. The impact on consumer health if all soft drinks, 'saft' and nectar contain intense sweeteners instead of sugar, including:
    - Do intense sweeteners affect the production of insulin in the body, and how will this affect the consumer?
    - What will the effect be on the total intake of intense sweeteners and the preservative benzoic acid if intense sweeteners replace sugar in all soft drinks, 'saft' and nectar?
    - How will dental health be affected if intense sweeteners replace sugar in all soft drinks, 'saft' and nectar?

2 Nectar was not included in the terms of reference when VKM received the task, but was included at a later stage.

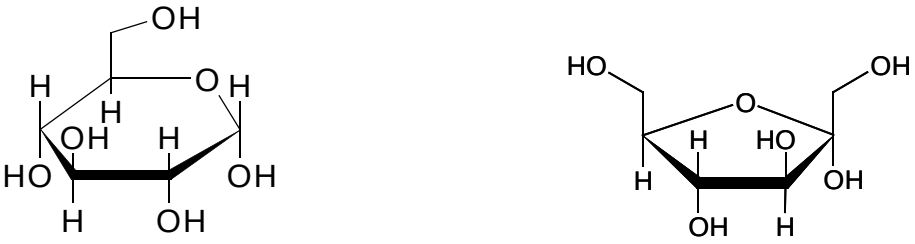
4 Definitions and terms

4.1 Sugars

The word ”sugar” is used in many different contexts. Sugar is used in connection with groceries such as castor sugar and sugar lumps, with nutrients such as sucrose, fruit sugar and milk sugar, and with physiological terms such as blood sugar and stored sugar.

In addition to provide a sweet taste, sugar has other technical properties, such as a preservative effect in jams, syrups, ‘saft’, etc.

Monosaccharides are the simplest form of carbohydrates. They consist of one sugar molecule. Examples of monosaccharides include glucose (grape sugar), fructose (fruit sugar), galactose and ribose. Monosaccharides are the building blocks of disaccharides and polysaccharides (such as starch and cellulose). A disaccharide is a carbohydrate composed of two monosaccharides. Sucrose (cane sugar/beet sugar) is composed of glucose and fructose.



α–**D-glycopyranose** α–**D-fructofuranose**

Figure 1. Examples of molecule structures of glucose and fructose

This report deals with the health-related impact of added sugars to soft drinks, ‘saft’ and nectar. By added sugar is meant all purely produced sugars (mono- and disaccharides) that are used as ingredients in soft drinks, ‘saft’ and nectar. The majority of the sugars added to soft drinks and ‘saft’ in Norway are sucrose, although fructose is also used.

In other countries and in other foodstuffs than drinks many different forms of added sugars are used, e.g. malt dextrin, corn starch and corn syrup. These are not common in soft drinks in Norway, but may be added to some products.

4.2 Intense sweeteners

Regulation 21 December 1993 nr 1238 on food additives defines sweeteners as food additives used to impart a sweet taste to foodstuffs. The food additive regulation implements EC Directive 94/35/EC on sweeteners for use in foodstuffs. The recitals of this Directive state that the use of sweeteners is justified for the production of energy-reduced food, non-cariogenic foodstuffs or food without added sugars, for the extension of shelf life through the replacement of sugar, and for the production of dietetic products. Foodstuffs with sweetening properties, such as syrup and honey are excluded from the Directive.

Sweeteners are divided into two main categories; high intensity sweeteners and low intensity sweeteners (polyols). The latter category is not authorised for use in drinks.

Intense sweeteners include: Acesulfame K (E950), aspartame (E951), cyclamic acid and its sodium and calcium salts (E952), saccharin and its sodium, potassium and calcium salts (E954), sucralose (E955), thaumatin (E957), neohesperidin DC (E959) and the salt of aspartame-acesulfame (E962).

Children under the age of 12 months are defined as infants and children under the age of 3 years are defined as young children. The placing on the market of foodstuff intended for this age groups are regulated in the Regulation 18 October 2002 No 1185 on processed cereal based food for young children and other food for infants and young children. The food additive regulation has in addition specific rules towards this food category. Young children are considered to be a vulnerable group and it is considered necessary to lay down strict rules for the use of additives in food for this group. Sweeteners, colourings and preservatives are thus not authorised for use in foods intended for infants and young children (< 3 years).

4.3 Preservatives

Regulation 21 December 1993 nr 1378 on food additives defines preservatives as substances that prolong the shelf life of foodstuffs by protecting them against deterioration caused by micro-organisms. The food additive regulation implements the EC Directive 95/2/EC on food additives other than colours and sweeteners.

Benzoic acid and benzoates are preservatives for use in certain foodstuffs. Benzoic acid is an aromatic acid which is present naturally, especially in cloudberries, lingonberries and cinnamon. Benzoic acid is relatively insoluble and it is common to use its salts, sodium benzoate, potassium benzoate and calcium benzoate (benzoates).

Benzoic acid and benzoates reduce the bacteria's ability to use the water present in the product and are therefore efficient in preventing the growth of bacteria. They are only efficient in an acid environment (pH<5.5) as will be found in many beverages.

It is prohibited to use benzoic acid and benzoates as preservatives in foods intended for infants and young children (< 3 years).

4.4 Soft drinks

Soft drinks included in the exposure assessment in this report are sodas with or without gas (sweetened with sugar or intense sweeteners), ice tea, non-alcoholic cider, tonic, Russian water, sport drinks, Battery ("energy-drink"). Other beverages may be included in the term "soft drink" in the literature discussed in this report, and other terms than "soft drinks" may have been used in these studies.

4.5 'Saft'

'Saft' is a traditional Norwegian product subject to national legislation, and cannot be translated directly into English. 'Saft' is defined as a concentrate produced from fruit juice which may contain sugar (mono- and disaccharides only) at specified levels but not water. 'Saft' may contain intense sweeteners but not flavourings.

If the product contains flavourings, the product cannot be marketed as 'saft' according to the definitions in regulation 10 December 1971 nr 01 on vegetable preserves. This regulation gives the quality parameters which must be met in order to produce a legal 'saft'. There are many concentrates on the market which do not fulfil these requirements and therefore are marketed as 'drinks' or squashes.

'Saft' is a fruit concentrate and shall be mixed with water before drinking.

4.6 Nectar

Nectar is an unfermented product consisting of fruit juice, water and sugar. Nectar is defined in annex I (4) of regulation 2 September 2003 on fruit juice and similar products. This regulation implements Council Directive 2001/112/EC relating to fruit juices and certain similar products intended for human consumption.

The fermentable, but unfermented product obtained by adding water and sugars and/or honey to fruit juice, fruit juice from concentrate, concentrated fruit juice and dehydrated/powdered fruit juice, to fruit puree or to a mixture of those products, that product, moreover, meeting the criteria in annex III of the regulation.

The addition of sugars and/or honey is permitted up to 20% of the total weight of the finished product.

If fruit nectars are manufactured without added sugar or with low energy value, sugars may be replaced completely or partially by sweeteners in accordance with regulation 21 December 1993 no 1378 on food additives for use in foodstuffs.

4.7 Body Mass Index (BMI) and BMI Z-score

Body Mass Index (BMI) is defined as the individual's body weight divided by the square of the height, and is expressed in the unit kg/m^2.

In a tertiary setting, BMI can be compared with a reference data set, and be reported as a Z-score. The BMI-for-age-Z-score needs to be calculated using a suitable software program according to the following formula:

$$\frac{\text{(observed value)-(median reference value of a population)}}{\text{standard deviation of reference population}}$$

Use of BMI-for-age-Z-scores allows a more detailed statistical description of individuals, particularly individuals at extremes of BMI.

4.8 Overweight and obesity

Body mass index (BMI, kg/m^2) is the measurement most commonly used for classification of body weight related to health or the risk of developing diseases. Table 1 illustrates the classification of weight and BMI in adults.

Table 1. Classification of weight in adults (WHO, 2000)

Weight classification	BMI (kg/m^2)
Underweight	< 18.5
Normal weight	18.5-24.9
Overweight	25.0-29.9
Obesity, grade I	30-34.9
Obesity, grade II	35-39.9
Obesity, grade III	>40

BMI varies with biological maturity. Consequently, the BMI varies according to age, and the International Obesity Task Force has published limit values for overweight and obesity specifically for age and gender for children between the ages of two and eighteen (Cole *et al.*, 2000).

4.9 Insulin resistance

Insulin resistance is a condition in which the body does not respond to insulin properly. It is a common cause of non-insulin dependent diabetes mellitus.

4.10 Acceptable Daily Intake (ADI)

The ADI is an estimate of the amount of a food additive, on a body weight basis, which can be ingested daily over a lifetime without appreciable health risk. The ADI is expressed as an interval from zero to the maximum acceptable intake, usually in the term of mg/kg body weight/day. ADI-levels for different food additives are established by the European Food Safety Authority (EFSA), the (former) EU Scientific Committee for Food (SCF) and/or by the Joint WHO/ FAO Expert Committee on Food Additives (JECFA).

4.11 95th percentile and median

In a distribution where all data are sorted by ascending order, the 95th percentile of the intake is the value where 95% of the data are below, and 5% are above this value. The median or the 50th percentile is the value where 50% of the data are below, and 50% are above this value.

4.12 Percent of energy (E%)

Fat, carbohydrates, proteins and alcohols contain energy in different amounts; approximately 37, 17, 17 and 29 kJ (9, 4, 4 and 7 kcal) per 100 g respectively. E% is the percent of the total intake of energy deriving from each of these nutrients.

4.13 Weighted average content

In this report, the weighted average values corrected for market shares for soft drinks, 'saft' and nectar are calculated based on information on actual content of aspartame, acesulfame K, cyclamic acid, saccharin, benzoic acid and sugar, and sales volumes provided by the food manufacturers. Example is given in Annex 1.

4.14 Spearman's rank correlation coefficient

Spearman's rank correlation coefficient is used as a linear relationship between two sets of ranked data; it measures how tightly ranked data cluster around a straight line. Spearman's rank correlation coefficient, like all other correlation coefficients, will take a value between -1 and +1. A positive correlation is one in which the ranks of both variables increase together. A negative correlation is one in which the ranks of one variable increase as the ranks of the other variable decrease. A correlation of +1 or -1 will arise if the relationship between the two variables is exactly linear. A correlation close to zero means there is no linear relationship between the ranks (Altman, 1991).

5 Trends in the consumption of sugar, intense sweeteners, soft drinks and 'saft'

Based on consumer studies and the national representative dietary surveys Ungkost 1993 (Statens ernæringsråd, 1997a) and Ungkost 2000 and Norkost 1993/94 (Statens ernæringsråd, 1997b) and Norkost 1997 (Johansson and Solvoll, 1999), this chapter shows the trends in the intake of sugar, intense sweeteners and consumption of sugared soft drinks and 'saft'.

The food consumption surveys made by Statistics Norway provide data on food articles purchased by private households. The surveys show that the daily consumption of added sugar in the average household increased from 70 grams per person per day in 1975 to 80 grams per person per day in 1999-2001. However, there was a decrease to 75 grams per person per day in 2002-2004. The consumption of sugared soft drinks and 'saft' increased with 80 g (from 140 g to 220 g) on average during the same period (personal communication with Kerstin Trygg, Assistant Professor, Department of Nutrition, University of Oslo – September 2006).

The national representative dietary surveys among adults (16-79 years), (Norkost 1993/94 and 1997), show that the intake of added sugar in the adult population remained unchanged during this period, with an average intake of approximately 55 grams daily in 1993/94 and 56 grams daily in 1997, which corresponds to about 9% of the energy from added sugar (Johansson *et al.,* 1999). No differences were found between men and women in the period from 1993-1997. The consumption of sugared soft drinks and 'saft' increased from an average of 185 grams/day in 1993/94 to 210 grams in 1997, whereas the consumption of soft drinks and 'saft' with intense sweeteners was almost unchanged (97 grams/day in 1993/94 and 91 grams/day in 1997). The increase in sugared drinks represents an average increase of consumption of 14%. This is a smaller increase than shown in the household surveys. An explanation for this might be that food consumption surveys in general show a higher consumption than the dietary surveys due to the methodological differences, and most important in this case might be that the household data include children.

In the two national representative dietary surveys among children and adolescents, (Ungkost 1993 and Ungkost 2000), two different dietary assessment methods were used (quantitative food frequency questionnaire and precoded diary, respectively). It is difficult to compare the data from these two studies in order to see a development over time. However, the data indicate that the consumption of added sugar among 13-year-olds has increased from about 12-13% of the energy from added sugar in 1993 to approximately 18% of the energy from added sugar in 2000 (Statens ernæringsråd, 1997a, Øverby and Andersen, 2002).

Data from the study "Helsevaner blant skoleelever" ("Health Habits among Students"), carried out by the Research Centre for Health Promotion (HEMIL-Center) at the University of Bergen, covering a nationwide representative selection of 11-, 13- and 15-year-olds in 1989, 1993, 1997 and 2001, reveal that the number of boys and girls who reported a daily consumption of soft drinks increased from 1989 to 2001 (Åstrøm *et al.,* 2004). The increase was consistent for all age groups. Boys and girls were four times more likely to drink sugar sweetened soft drinks daily in 2001 than in 1989.

The Norwegian Food Control Authority (SNT) conducted an intake study in 1992, where the objective was to estimate the intakes of acesulfame K, aspartame, cyclamate and saccharine in Norway, related to the ADI (Bergsten, 1993). A similar intake study among 1375 individuals

at the age of 16 to 80 years on the consumption of products that were artificially sweetened, was carried out in 1997 (Bergsten, 1998). These two studies were not based on the national representative dietary surveys, and the methods for estimating the intake of intense sweeteners differed in the two studies. It is therefore difficult to compare the data from these studies with each other and with the conclusions in this report from VKM.

Figures from the Norwegian Brewers and Soft Drinks Producers (Bryggeri- og mineralvannforeningen) substantiate the increase in the sales of sugared sodas from 1950 up until 2002, while there seems to be a minor reduction from 2003 to 2004 (see Figure 2). Approximately 71% of the sodas consumed in 2004 had added sugar. There has been a small increase in the consumption of sodas with intense sweetener from 1991 to 2004.

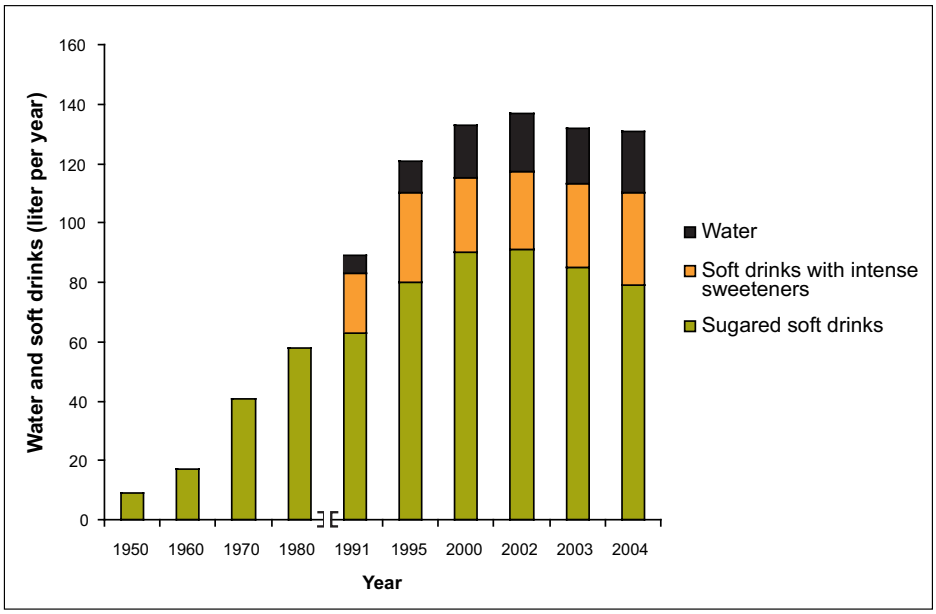


Figure 2. Consumption of water, sodas with intense sweeteners and sugared sodas in litres per person per year (Norwegian Brewers and Soft Drinks Producers, 2004)

Figures from Canadean Ltd[3] show a small decrease in the total consumption of carbonated soft drinks in Norway from 2002 to 2006[4] from 531 million litres in 2002 to 516 litres in 2006 (provisional). According to Canadean reports the consumption of carbonated soft drinks with intense sweeteners in Norway has increased from 22% of the market share in 2002 to an expected 38% of the market share in 2006.

Bottled water and flavoured water are not included in the exposure assessments in this report. According to figures from the beverage industry[5], the sales figures for bottled water and water flavoured with intense sweeteners and sugars have increased from 2004 to 2006.

The last national representative dietary surveys are from 1997, 1998/99 and 2000 for different age groups. It is likely that the consumption pattern has changed the last years. The sales figures indicate changes, but this has not been confirmed in new national dietary surveys. Changes in sales figures do not differentiate between age groups in the population.

3 Canadean is a global market research and data management company focusing on the international beverage industry and its suppliers
4 Figures from 2006 are estimates
5 AC Nielsen Scantrack (Groceries sales only)

5.1 Summary of trends in the consumption of sugar, intense sweeteners, soft drinks and 'saft'

Both food consumption surveys and national representative dietary surveys show that the consumption of added sugar and sugared soft drinks and 'saft' has increased over the last decades.

According to sales figures after 2002 from Canadean Ltd, the consumption pattern of carbonated soft drinks seem to be changing as the sales of carbonated soft drinks with intense sweeteners are increasing, while the sales of sugar sweetened carbonated soft drinks are decreasing. The sales figures for carbonated soft drinks (sugared and intense sweetened) show a small decrease in consumption from 2002 to 2006. It remains to be seen whether this is an enduring trend, and if so, in what age groups these changes have occurred. According to figures from the beverage industry, the sales figures for bottled water and water flavoured with intense sweeteners and sugars have increased from 2004 to 2006.

6 Health consequences (overweight, diabetes, dental health) associated with consumption of soft drinks

This chapter will focus on the association between consumption of drinks with sugar/intense sweeteners and the risk of overweight, diabetes and dental caries/erosions. Other health consequences from intake of sugar in general have been thoroughly described in the Danish report "Sukkers sundhedsmæssige betydning" ("The Health Importance of Sugars") (Danish Nutrition Council, 2003).

6.1 Methodological considerations for evaluation of epidemiological studies

The knowledge about the association between consumption of soft drinks and different health parameters is mainly based on nutritional epidemiological studies. This section includes a short description of different types of epidemiological studies and possible methodological advantages and weaknesses connected with these studies.

Nutritional epidemiological studies can be separated into observational and experimental studies. Within observational studies are case control studies, cross-sectional studies and cohort (longitudinal/prospective) studies. Within experimental epidemiological studies are randomized clinical trials, field trials and community intervention trials.

A *cross-sectional study* measures determinants of health (e.g. sugared soft drinks) or the prevalence of health outcome (e.g. diabetes type 2), or both, in a population at a given point in time. It provides a snapshot of the health experience of a population at that time. Such information can be very useful in assessing the health status and needs of a population. It can also be used to study the relationship between variables. However, associations must be interpreted with caution. In general, the relationship between cause and effect in a cross-sectional study cannot be established.

In a *cohort (longitudinal/prospective) study* healthy subjects are followed over time, typically with repeated monitoring of exposure (e.g. consumption of soft drinks) and health outcome. It enables comparison of individuals who are exposed to certain food items/nutrients with individuals without this exposure or with a different level of exposure, in order to determine if there is a difference in health outcomes between the subjects. In these studies information about exposure (dietary intake) is often self-reported. Exposure data are collected before the subjects have the disease/health outcome of interest.

One type of experimental epidemiological study is an *intervention study*. In an intervention study the subjects are selected from one population. After baseline the total study group is split into a group that receives the intervention and a group that does not receive the intervention (control group). The comparison of the outcomes of the two groups at the end of the study period is an evaluation of the intervention.

Controlled clinical trials constitute a separate class of intervention studies. Controlled clinical trials are designed to evaluate the effectiveness of one or more forms of medical treatment. Often subjects are randomized to different treatments. Randomizing, especially when randomizing is blinded for the subject, reduces potential errors.

The main emphasis in this chapter is on data from prospective population studies (cohorts) as well as diet intervention studies of some duration, as these provide a better basis than cross-sectional studies. The results from prospective studies may be confounded. A confounder in the present situation is a factor associated with soft drink consumption and which at the same time is a risk factor for the endpoint under study (e.g. overweight), independent of it association with soft drink consumption. Most of the prospective studies included in this chapter are adjusted for potential confounding factors such as e.g. age, gender, smoking and social class.

Another challenge in prospective studies is errors associated with self-reported data such as dietary intake, body weight and height. Several studies have found that food items considered unhealthy, and also between meal snacks are most likely to be underreported (Poppitt *et al*., 1998, Lafay *et al*., 2000). Studies have also found that both men and women underreport body weight and overreport height, which again may contribute to underestimation of BMI (DelPrete *et al*., 1992, Niedhammer *et al*., 2000).

Relevant articles for section 6.2 and 6.3 were identified by searching the MEDLINE database of articles for prospective cohorts and experimental studies of the intake of sugar sweetened beverages/beverages sweetened with intense sweeteners and weight gain, overweight and/or obesity, diabetes type 1 and 2. Key words such as 'soda', 'sugar sweetened beverage', 'sugar sweetened soft drinks', 'diet soda', 'soft drinks with intense sweetener', 'beverages with intense sweetener', 'weight gain', 'overweight', 'obesity', 'diabetes type 1'and 'diabetes type 2' were used alone or in combination in the search. Additional published reports were obtained and reference lists in articles were consulted.

6.2 Sugar/intense sweeteners from soft drinks/'saft' and weight regulation

For the body weight to remain stable, the energy intake must equal the expenditure of energy. Food can influence both sides of the energy balance, but is likely to have a greater effect on the energy intake and regulation of the appetite than on the energy expenditure where food-induced thermogenesis[6] is playing a role.

6.2.1 Prevalence of overweight and obesity

The average weight and the percentage of obese people have increased in the adult Norwegian population during the past decades. Development of BMI in three Norwegian counties is given in Table 2. For men, there has been a gradual increase since the 1960s. For women, there was a reduction of the average BMI from the 1960s to the 1970s. However, from 1980 there has been an increase for both sexes (Directorate for Health and Social Affairs, 2000). In studies from 2000-2003, the prevalence of obesity (BMI ≥30) was 19.5% for men and 20% for women (median values, all age groups included). The median values among 40-45 year-old men and women in these latest studies were 18.5% and 16% respectively (Ulset *et al*., 2007). These data confirm that there are no signs of this trend abating or reversing.

6 Food-induced thermogenesis is energy expenditure from digesting food. The average increase in energy-expenditure from digesting food is approximately 10%

Table 2. Development of BMI in successive generations of 40-42-year old men and women in three Norwegian counties in the period 1966-1999 (Adapted from Meyer and Tverdal, 2005)

Sex and time periods	Number of individuals	Mean BMI (kg/m²)	Proportions (%)		
			Normal weight[1] (BMI<25 kg/m²)	Overweight (BMI 25-29,9 kg/m²)	Obese (BMI ≥ 30 kg/m²)
Men					
1966-69	4994	24.9	54.6	41.1	4.3
1974-	3323	25.0	54.0	40.1	5.9
1977-	3629	25.3	48.9	44.7	6.4
1985-	5418	25.5	47.6	44.3	8.1
1996-99	4922	26.5	34.9	50.4	14.7
Women					
1966-69	5223	25.4	53.8	33.4	12.8
1974-	3398	24.7	62.0	28.2	9.8
1977-	3657	24.0	68.9	24.6	6.5
1985-	5329	24.2	66.5	25.0	8.5
1996-99	5406	25.2	56.2	31.3	12.5

7 Includes underweight defined as BMI <18.5 kg/m²

The data available to review the development of overweight among children and adolescents are limited. Comparisons of 13-year-olds in 1993 to 13-year-olds in 2000 revealed a 50% increase in overweight among children during these seven years, from approximately 7% to 11.5% (Andersen *et al.,* 2005a). Ungkost 2000 also showed a higher incidence of overweight among 9-year-olds than 13-year-olds (18.0% and 11.5%, respectively). Results from the latest study performed in Oslo in 2004 among 8-year-olds (n = 3453) and 12-year-olds (n = 3597) show that the prevalence of overweight among 8- to 12-year-olds is 21% (Vilimas *et al*., 2005).

6.2.2 Re-formation of fat from carbohydrates

For the past decades there has been a discussion on the degree of human capacity to transform carbohydrates to fat, and whether sugar is fattening or not (Mølgaard *et al.,* 2003).

Humans have the requisite enzymes for transforming carbohydrates into fat (*de novo* lipogenesis) (Hellerstein, 2001). Research indicates that *de novo* lipogenesis only contributes to fat accumulation in cases of over eating a diet rich in carbohydrate. In such a situation the energy from carbohydrates must be higher than the total energy expenditure (Hellerstein, 2001, Minehira *et al.,* 2003, Minehira *et al.,* 2004, Strawford *et al.,* 2004). *De novo* lipogenesis is the result of complex processes and many studies are difficult to interpret. The conversion of dietary fat into body fat is much more efficient than that of dietary carbohydrates. If the intake of carbohydrates is less than the energy expenditure, fatty deposits will normally originate from fat in the food. A Norwegian average diet containing approximately 50% of the energy (E%) from carbohydrates and 30-40E% fat, will therefore hardly cause a significant net *de novo* lipogenesis from carbohydrates (McDevitt *et al.,* 2001, Molgaard *et al*., 2003). A diet very rich in carbohydrates (60-70E%) combined with overeating and a large content of simple carbohydrates can, on the other hand, lead to an increased *de novo* lipogenesis and an increased concentration of plasma triglycerides (Hellerstein, 2001, Minehira *et al.,* 2004, Strawford *et al.,* 2004).

6.2.3 Sugared soft drinks/'saft' and overweight

In August 2006, a review paper on the relation between consumption of sugared soft drinks and weight gain was published in the American Journal of Nutrition (Malik *et al*., 2006). The conclusions made in this section are based on this review, the original papers referred to in the review, and a few other relevant papers identified through the MEDLINE search.

6.2.3.1 Prospective population studies

Malik *et al.* (2006) identified 10 prospective studies, 6 in children and 4 in adults that have explored the association between the intake of sugared soft drinks and a change of the body mass index (BMI) or weight. The study by Welsh *et al.* identified by Malik *et al.* (2006) is not included in this report, since they include juices in their category of sweetened drinks. Table 3 shows the prospective studies included. The definition of soft drinks varies from paper to paper but in general sugar sweetened soft drinks encompasses sodas (sugar sweetened carbonated beverages such as colas) along with other sugar sweetened beverages such as fruit drinks, lemonade and ice tea.

Four of the studies in children and adolescents found significant positive associations between the intakes of sugar sweetened beverages and an increase in overweight or obesity. The largest study was a 3-year follow-up of 11654 children (9-14 years old) completing questionnaires in 1996, 1997 and 1998, where a significant association between consumption of sugar-added beverages (soda, sweetened iced tea, noncarbonated fruit drinks) and weight gain was observed in both boys and girls (Berkey *et al*., 2004). Boys who increased consumption of sugar-added beverages from the prior year experienced weight gain (0.04 kg/m^2 increase in BMI/additional serving, p = 0.01). Children who increased intakes by 2 or more servings/day from the previous year also gained weight (0.14 kg/m^2 in boys, p = 0.01; 0.10 kg/m^2 in girls, p = 0.046). In a smaller study of 548 American children (average age 11.7 years), intake was collected using a FFQ while height and weight were measured (Ludwig *et al.,* 2001). Ludwig *et al*. (2001) showed that children with a high consumption of sugar sweetened soft drinks (approximately 0.3 litres per day of sugar sweetened soda, sugar sweetened fruit drinks and ice tea) had an increased risk of weight increase over a period of 19 months. For each additional serving of sugar sweetened drink during the period there was a 60% increased risk of developing obesity. In a small study by Phillips *et al.* (2004) 141 children (baseline age 8-12 years) were followed for 4 years. They collected intake data by a FFQ, and measured weight and height annually. Phillips *et al*. found a positive association between soda consumption and BMI z-score, however no relation with the percentage of body fat. The authors could not explain why they observed an association between soda consumption and BMI z-score and not with percent body fat. Two studies in children reported non-significant associations between the consumption of sugar sweetened beverages and BMI (Newby *et al.*, 2004, Blum *et al.,* 2005). Newby *et al.* (2004) examined the association between the consumption of sugar sweetened beverage and changes in weight and BMI in preschool children followed for 6-12 months. No significant association between soda intake and annual changes in BMI was found. The small study by Blum *et al.* (2005) (n = 166) did not find a significant association between changes in consumption of sugared beverages and BMI z-score.

The review by Malik *et al.* (2006) identified four studies examining the relation between intake of sugar sweetened beverages and weight gain in adults. The most extensive study includes 51603 American women who completed food frequency questionnaires (FFQ) in 1991, 1995 and 1999, and reported weight and height (Schulze *et al*., 2004). The study demonstrated that women who increased their intake of sugar sweetened carbonated soft drinks during the follow-up period of 8 years, had a larger increase in weight (BMI) than women who did not change, or reduced, their intake of sugar sweetened carbonated soft drinks. In a Mediterranean population of 7194 men and women (mean age 41 years) dietary intake was collected by FFQ and body weight and height were self-reported (Bes-Rastrollo *et al.*, 2006). They were followed for a median of 28.5 months. A significant association was found between high consumption of sugar sweetened carbonated beverages and weight gain among the participants who had a weight gain > 3 kg in the 5 years before baseline. The adjusted odds ratio of subsequent weight gain for the fifth quintile compared with the first quintile of sugar sweetened carbonated soft drinks was 1.6 (95% CI (confidence interval) of 1.2, 2.1; p trend = 0.02) (Bes-Rastrollo *et al.*, 2006). On the other hand, a Norwegian study of 215 women and 207 men with a follow-up period of 8 years (from the age of 25 to 33) found no relation between the long-term intake of sugar sweetened carbonated soft drinks and overweight/obesity at the age of 33 (Kvaavik *et al*., 2005). No significant association was observed between soda consumption and weight gain in a study among 3552 health workers in the United States (French *et al.,* 1994).

The strength of all these studies is the longitudinal design. This design allows studying changes over time in beverage consumption and BMI while accounting for growth and maturation in the studies among children and adolescents. Both in the study by Berkey *et al*. (2004) and Ludwig *et al.* (2001) they adjusted for Tanner stage[7] and/or menarche (girls).

7 Tanner stages are stages of physical development in children, adolescents and adults. The stages define physical measurements of development based on external primary and secondary sex characteristics

However, all the studies are observational in nature and cannot confirm causality. In order to clarify the connection between sugar sweetened soft drinks and body weight, it is therefore important to carry out controlled intervention studies.

Table 3. Prospective studies

Reference	Population	Duration follow-up	Beverage category	Results
Children				
Berkey *et al.*, 2004	N=11654, 9-14 y	3 year	Sugar sweetened drinks	Boys who increased consumption of sugar-added beverages from the prior year experienced weight gain (0.04 kg/m^2 increase in BMI/additional serving, p=0.01). Children who increased consumption by 2 or more servings/day from the prior year gained weight (0.14 kg/m^2 in boys, p=0.01; 0.10 kg/m^2 in girls, p=0.046)
Ludwig *et al.*, 2001	N=548 11.7 (0.8) y	19 month	Sugar sweetened drinks, diet soda	Significant association between sugar sweetened beverage consumption and BMI, for each additional serving of sugar sweetened beverage per day during the period BMI increased by 0.24 kg/m^2 p=0.03 and there was a 60% increased risk of developing obesity
Phillips *et al.*, 2004	N=141 (only girls), 8-12 y	4 year	Soda	Significant association between soda consumption and BMI z-score. Subjects in the third and fourth quartiles of percentage of energy from soda had BMI z-score an average 0.17 units higher than those in the first quartile (p<0.0001)
Newby *et al.*, 2004	N=1345, 2-5 y	6-12 month	Soda, diet soda	No significant association between soda consumption and BMI change
Blum *et al.*, 2005	N=166, 9.3 (1.0) y	2 year	Sugar sweetened drinks, diet soda	No significant association between sugar sweetened beverage consumption and year 2 BMI z-score
Adults				
Schulze *et al.*, 2004	N=51603, 24-44 y	8 year	Sweetened soft drinks, diet soft drinks	Significant association between soft drink intake and weight gain
Bes-Rastrollo *et al.*, 2006	N= 7194, 41 y	28,5 month (median)	Sugar sweetened soft drinks, diet soda	Significant association was found between high consumption of sugar sweetened carbonated beverages and weight gain among the participants who had had a weight gain > 3 kg in the 5 years before baseline
Kvaavik *et al., 2005*	N=422, 23-27 y	8 year	Soda, diet soda	No significant association between soda consumption and change in BMI
French *et al.*, 1994	N=3552	2 year	Soda	No significant association between soda consumption and weight change

6.2.3.2 *Intervention studies*

In this report, focus has been on intervention studies that have limited their investigation to the effect of sugar sweetened soft drinks on the body weight, rather than studies that have investigated the effect of a diet with a high sugar content stemming from a combination of regular food and soft drinks. The studies included are shown in Table 4. The included studies had duration of at least 2 weeks, as an effect on the body weight and appetite regulation can only be expected after a certain period of time on a certain diet (Astrup and Raben, 1992). It is also most relevant to focus on *ad libitum* studies, i.e. studies designed to allow the subjects to eat as much as they like.

In a 10-week controlled intervention study, a group of overweight adults (n = 21) consumed a relatively large amount of sugar (28E%), mainly as fluids (1.3 litres per day), while the other group (n = 20) was given soft drinks with intense sweeteners instead of sugar (Raben *et al.*,

2002). The study showed that the group with a high intake of sugar in fluids increased their energy intake, body weight and fat mass significantly during the intervention period. The same did not apply for the group who was given soft drinks with intense sweeteners. In another controlled study, Tordoff and Alleva (1990a) gave 30 test persons with normal weight 1150 grams of carbonated soft drinks sweetened with high fructose syrup daily for 3 weeks or aspartame for 3 weeks. Compared to no soft drink consumption, the consumption of high fructose sweetened carbonated soft drinks significantly increased energy intake and body weight of both sexes, while the opposite was observed for soft drinks with aspartame.

James *et al.* (2004) carried out a randomised controlled trial (RCT) among 644 British children ranging from 7-11 years. They found that a school based educational program aiming to reduce the consumption of carbonated drinks (including diet carbonated drinks) was successful in producing a modest reduction (of 0.6 glasses per day in the intervention group, and an increase of 0.2 glasses per day in the control group). This was associated with a reduction in the prevalence of overweight and obesity. Following a 12-month intervention period the proportion of overweight and obese children in the control group increased by 7.5%, whereas the proportion in the intervention group decreased by 0.2%. Since the authors did not analyse the data with only sugar sweetened carbonated soft drinks, it cannot be concluded if sugared soft drinks are related to body weight based on this study.

In a small pilot RCT by Ebbeling *et al.* (2006) among 103 adolescents, aged from 13- to 18 years, the intervention group received weekly home-deliveries of non-caloric beverages for 25 weeks, while the control group continued their usual beverage consumption. Consumption of sugar sweetened beverages decreased by 82% (energy intake from sugar sweetened soft drinks was reduced with 1202 kJ) in the intervention group. No change was observed in the control group. Decreasing sugar sweetened beverage consumption had a beneficial effect on body weight.

Table 4. Intervention studies

Reference	Population	Design	Intervention	Results
Raben et al., 2002	N=41 (35 female, 6 male), 20-50 y	Parallel, 10 week	Daily supplement of foods and drinks with sucrose or artificial sweeteners	Body weight, fat mass and BMI increased in sucrose group and decreased in sweetener group, difference between groups were 2.6 kg 95% CI:1.3, 3.8, 1.6 kg 95% CI:0.4, 2.8 and 0.9 kg/m^2 95% CI:0.5, 1.4, respectively
Tordoff and Alleva, 1990a	N=30 (9 female 28 y, 21 male 23 y)	Cross-over, 3x3 week	1150 g soda with aspartame vs. soda with high fructose syrup or no soda	Relative to no soda, high fructose syrup soda significantly increased weight in females (0.97 kg, $p<0.01$), no significant increase in males. Aspartam sweetened soda decreased weight in males (0.25 kg, $p<0.05$) but not in females
James *et al.*, 2004	N=644, 7-11 y	RCT, One school year	Focused educational program on nutrition and drink consumption	A modest reduction of 0.6 glasses of soft drinks (both with added sugar and diet) per day in the intervention group, and an increase of 0.2 glasses per day in the control group. This was associated with a reduction in the prevalence of overweight and obesity. Following a 12-month intervention period the proportion of overweight and obese children in the control group increased by 7.5%, whereas that in the intervention group decreased by 0.2%
Ebbeling *et al.*, 2006	N=103, 13-18 y	RCT, pilot, 25 week	Weekly home delivery of noncaloric beverages (4 servings/day)	Decreasing sugar sweetened beverage consumption had a beneficial effect on body weight in subject with baseline BMI > 30

6.2.3.3 *Discussion of results in prospective population studies and intervention studies*

Thirteen studies were included in the overview, 9 prospective cohort studies and 4 experimental studies. Five of the 9 prospective studies found that an increase in the consumption of sugared soft drinks was significantly associated with greater weight gain and greater risk of obesity over time in both children (Ludwig *et al*., 2001, Berkey *et al.*, 2004, Phillips *et al.*, 2004) and adults (Schulze *et al*., 2004, Bes-Rastrollo *et al.*, 2006). A 1-year intervention study found that reducing soft drink consumption in school children led to significant reduction in the prevalence of overweight and obesity (James *et al*., 2004), and a 25-week RCT in adolescents found that reduction in the intake of sugar sweetened beverages had a beneficial effect on body weight that was strongly associated with baseline BMI (Ebbeling *et al.*, 2006).

Sample size and follow-up

Sample size and duration of follow-up of the prospective studies varied. The largest prospective study among children by Berkey *et al.* (2004), including more than 11000 children followed for 3 years, found a significant association between consumption of sugar sweetened beverages and weight gain. The smaller study by Blum *et al.* (2005), including only 166 individuals, did not observe an association between sugar sweetened beverages and year 2 BMI z-score. The small number of children may have limited the statistical power to find an association. Newby *et al.* (2004) also found no significant association between soda consumption and annual change in BMI among 1345 children. The short follow-up period of 6-12 month may not be sufficient to study the relation between soft drinks and weight. Furthermore the children included were preschoolers and may have been too young to study the relation between soft drinks and weight. Two of the prospective studies among adults had long follow-up periods (8 years). In the study by Schulze *et al.* (2004) a significant positive association between soda consumption and weight gain was observed. Kvaavik *et al.* (2005) found no significant positive association between soda consumption and obesity in men. However, their sample size was small and the stratification of subject for subgroups may have limited the power of the study. The intervention studies also varied in time and number with the RCTs having the longest duration and sample size.

Dietary intake data

The dietary assessment methods used to estimate beverage consumption also need to be thoroughly considered. Each method has its own set of errors that could be manifested in the effect estimates. Especially selective underreporting of the intake of sugared soft drinks may be a challenge in prospective studies. This is particularly valid for overweight people who have been found to under-report their energy intake to a larger degree than people of normal weight (Lichtman *et al*., 1992, Johnson *et al*., 1994, Braam *et al*., 1998, Black, 2000). In addition, because the relation between beverage consumption and weight is longitudinal, a tool that can assess long-term consumption patterns, such as an FFQ, would be most appropriate. Four of the 5 prospective studies among children used FFQ, while Blum *et al.* (2005) used 24-hour diet recall at baseline and study exit, which may have further limited the power of the study. Three of the prospective studies among adults used validated FFQs (Schulze *et al.* 2004, Bes-Rastrollo *et al.*, 2006, Kvaavik *et al.,* 2005). Kvaavik *et al.* (2005) used two different questionnaires during follow-up before including a FFQ; this could have lead to some degree of misclassification of beverage consumption and attenuation of actual effects. French *et al.* (1994) used a short FFQ specially designed for the study. Omission of certain food items commonly consumed with soda/sweetened beverages could affect the reporting of beverage consumption and the ability to control for confounding.

Weight and height

Several of the studies include self reported weight and height (Berkey *et al.*, 2004, Bes-Rastrollo *et al*., 2006, Schulze *et al.*, 2004) which may introduce an error because of selective underreporting of body weight (Spencer *et al*., 2002, Elgar *et al*., 2005). In the studies by Ludwig *et al.* (2001) and Phillips *et al.* (2004) the weight and height were measured, however, these studies were relatively small. The use of BMI as a measurement of obesity may also introduce an error.

Although BMI is a widely used measurement one cannot fully control for changes in body composition over time resulting, for instance, from puberty or fitness training.

Repeated measures
The most comprehensive evaluation of diet and weight involves repeated measures of both diet and weight over time. Two of the prospective studies among children and adolescent (Ludwig *et al.*, 2001, Berkey *et al.*, 2004) and one among the adults (Schulze *et al.,* 2004) reported changes in both consumption and body weight, Whereas repeated measures of diet and weight are useful for characterising longitudinal relations, it is important to acknowledge that longitudinal studies are not immune to the problem of reverse causation (i.e. persons change their diet because of their weight) that commonly plagues cross-sectional analysis, because longitudinal analyses typically compare changes in one variable with changes in another.

Confounding
Although prospective studies more easily can be controlled for confounding than cross-sectional studies, they still are observational of nature and may not completely separate the effect of other aspects of diet and lifestyle from the effect of sugared beverages on weight. For instance, it may be difficult to ascertain whether the weight gain results from the consumption of calories in soda itself or from calories in foods often eaten in conjunction with soda.

6.2.3.4 *Does fluid sugar satiate less than solid form sugar?*

A probable cause for the body weight increase in the above-mentioned studies may be that all or the majority of the added sugar is provided as a fluid (in the form of sugared soft drinks). Calories from fluids seem to satiate less than calories from solid foods, and will thus provide extra calories that are not compensated for by reduced food consumption. Therefore, such foodstuffs may lead to a surplus of calories and weight increase. Several experimental studies have been carried out on this issue.

DiMeglio and Mattes (2000) gave 15 people an additional 1880 kJ/day, either as "jelly beans" or as sugar sweetened drinks for a period of 4 weeks in a cross-over design. They observed that the intervention group reduced their energy intake from other foods during the 4-week period of additional sugar in solid form (jelly beans) compared to the period when the sugar was given as drink, in which case the overall energy intake increased. A significant weight increase was observed to result from the period of sugar sweetened drinks.

Almiron-Roig *et al.* (2003) tested the effect of eating an isocalorific amount of biscuits or sugar sweetened drinks at different hours prior to a main meal in a group of 32 men and women. The results indicated that snacking between meals may increase the overall intake of energy, whether the snack consists of solid foods or drinks.

In a literature review by Mattes (1996), including 42 studies, extra energy in the form of fluids was found not to induce a downsizing of the remaining energy intake. Extra energy added in the form of semi-fluid foods such as for example blancmange and ice-cream led to a certain reduction of the remaining energy intake, while extra energy provided as solid food or in a mixed meal led to the largest reduction in the remaining energy intake of the day. This literature review therefore indicates that energy supplied as fluids does not reduce the remaining energy intake to as large a degree as energy supplied as solid foods.

There have been speculations on why fluids may not have the same satiating effect as solid foods (Mattes, 1996, DiMeglio and Mattes, 2000, Amiron-Roig *et al*., 2003). A faster passage through the gastro-intestinal tract, reduced expansion of the ventricle, no chewing, and weaker stimulation of the satiation signals compared to the effects of solid foods might be potential underlying mechanisms.

The results are not clear, but there is a tendency for the test persons not to reduce their energy intake from solid foods to compensate for the extra energy from sugared drinks, so that the overall intake of energy increases. However, the majority of these intervention studies are short-term with relatively few test individuals, and the conclusions that can be drawn from the studies with respect to long-term effects of satiation and weight regulation are therefore limited.

6.2.3.5 *Summary of sugared soft drinks/'saft' and overweight*

Available epidemiological literature supports a positive link between sugar sweetened soft drinks and the risk of overweight and obesity. However, interpretation of the published studies is complicated by several method-related issues, including small sample sizes, short duration of follow-up, lack of repeated measures in dietary exposures and outcomes, and confounding by other diet and lifestyle factors.

The WHO's Technical Report No. 916 "Diet, Nutrition and the Prevention of Chronic Diseases" states that the data basis for claiming that a high intake of sugar sweetened drinks promote weight increase was considered to be moderately strong (WHO, 2003).

6.2.4 Soft drinks/'saft' with intense sweeteners and weight regulation

In a report from 2004, the American Dietetic Association (ADA) stated that intense sweeteners do not cause an increase in appetite and food consumption, and that people intending to lose weight can use intense sweeteners within the framework of a healthy diet (ADA, 2004).

The following chapter is a review of studies that have investigated the relation between consumption of soft drinks with intense sweeteners and weight gain. In addition, there have been included some studies examining the intake of intense sweeteners and weight gain.

6.2.4.1 *Prospective studies*

In a cohort of 31940 middle-aged women from the "Nurses' Health Study and a follow-up time of 8-years, saccharin intake was positively related to change (gain) in body weight (significantly) (Colditz *et al*., 1990). Similar results were observed in a British study among 465 adults aged from 18-64 years and a follow-up period of 4-5 years (Parker *et al*., 1997). Parker *et al*. (1997) found that the intake of saccharine was significantly associated with tertiles of weight changes (increase in body weight) among the women. In a study of 548 American children (average age 11.7 years) Ludwig *et al*. (2001) showed that a change in consumption of sodas with intense sweeteners over a period of 19 months was negatively associated with incidence of obesity (odds ratio 0.44, $p = 0.03$). In the study by Berkey *et al.* (2004) among > 11000 children and adolescents (9-14 years) they found that drinking diet soda during the previous year was associated with weight gain among boys, but not among girls. The authors explain this phenomenon with that the heavier boys in their study were not substituting diet soda for sugared soda but were drinking diet sodas in addition.

Only two prospective studies specifically looking at the association between consumption of soft drinks with intense sweeteners and body weight were found (Ludwig *et al*., 2001, Berkey *et al*., 2004). The results from these studies were not consistent. These two studies were thoroughly discussed in section 6.2.3.1. In general the discussion of limitations in section 6.2.3.3 is applicable to these studies.

6.2.4.2 *Intervention studies*

Most intervention studies on the relation between the intake of intense sweeteners/ consumption of soft drinks with intense sweeteners and weight regulation are short-term studies, lasting from a few hours to a few days. There are only two *ad libitum* intervention studies of more than 2 weeks' duration (Tordoff and Alleva, 1990a, Raben *et al*., 2002). In addition, three studies have been identified where the main purpose of using beverages with intense sweeteners was weight reduction.

In the above-mentioned studies by Raben *et al.* (2002) and by Tordoff and Alleva (1990a) (see section 6.2.3.2 for more details about these studies) the test persons were given additions of sugared foods or the equivalent weight of foods sweetened with intense sweeteners over a period. In the study by Raben *et al.* (2002) the group consuming foods with intense sweeteners over a period of 10 weeks, decreased significantly in body weight and fat mass. Tordoff and Alleva (1990a) reported significant decrease in body weight in males consuming high amounts of soda with intense sweeteners over a 3 week period compared with a condition of no-consumption. No reduction in body weight was observed among women.

Porikos *et al.* (1982) studied 6 individuals of normal weight who were encouraged to drink sugared soft drinks for 6 days, then soft drinks with aspartame for 12 days and finally 6 days with sugared soft drinks. The results showed a weight increase during the period of sugar sweetened soft drinks, but not during the period of soft drinks with aspartame.

Kanders *et al.* (1988) studied the effect of including food and beverages containing aspartame in a 12-week weight reduction scheme among 59 obese men (n = 13) and women (n = 46). Among the women who were given aspartame, a slightly higher weight loss was observed than in the control group (7.5 kg vs. 5.8 kg), while the men achieved a clinically significant weight loss in both groups.

Blackburn *et al.* (1997) studied the effect of aspartame as part of a weight reduction scheme among 163 obese women. The women were randomly assigned to consume or to abstain from aspartame-sweetened foods and beverages. The intervention period lasted 16 weeks and after that there was a 12 month maintenance phase. Three years after the intervention, the aspartame group had achieved an average weight loss of 5.l kg, while the weight in the group without aspartame had remained unchanged since the start of the study. This difference was significant.

There have been conducted a series of short-term studies of less than 2 weeks duration. In many of these studies subjects have received a test meal and the effect of the meal has been assessed the same day and/or the following days. Some small short-term studies have indicated that aspartame and saccharin can stimulate the appetite (Lavin *et al.*, 1987, Rogers and Blundell, 1989, Tordoff and Alleva, 1990b, Rogers *et al.*, 1995). However, the majority of the short-term studies have not been able to document that an intake of intense sweeteners leads to an enhanced appetite or increased energy intake (Rodin, 1990, Canty and Chan, 1991, Black *et al*., 1991, 1993, Rogers *et al*., 1995, Beridot-Therond *et al*., 1998, Hall *et al*., 2003). The effects of aspartame on the regulation of the appetite have also been studied in children, without any appetite stimulating effect being observed (Anderson *et al*., 1989, Birch *et al*., 1989, Wilson, 2000).

6.2.4.3 *Summary of soft drinks/'saft' with intense sweeteners and weight regulation*

The majority of the published studies indicate that intense sweeteners do not lead to an increase in the energy intake and body weight. However, most of the intervention studies are short-term studies with a small number of study subjects. These studies often only include obese subjects and the conclusions that can be drawn from them with respect to long-term effects of satiation and weight regulation are therefore limited.

6.3 Sugar/intense sweeteners from soft drinks/'saft' and diabetes

6.3.1 Prevalence of diabetes

The prevalence of known diabetes (type 1 and 2) in Norway, adjusted for gender and age, has been estimated to 2.3%. The total number of persons with diagnosed diabetes type 1 and 2 in Norway is in the order of 90000-120000, of which about 20000 have diabetes type 1. However, some data suggest that there may be an almost equal number of persons with undiagnosed type 2 diabetes (Stene *et al.,* 2004). The prevalence increases with age. In the age group 70-79 years the prevalence is approximately 8%.

6.3.2 Sugar and type 1 diabetes

Some studies have addressed the possible relation between sugar consumption and risk of type 1 diabetes (Thorsdottir and Ramel, 2003, Virtanen and Knip, 2003). Present data do not seem to justify the conclusion that high levels of sugar intake contribute to an increased risk of developing type 1 diabetes. Diabetes type 1 is clearly the result of an autoimmune attack on insulin-producing pancreatic beta-cells. It has been suggested that e.g. short duration of breast feeding, introduction of cow milk or cereal consumption in infants may contribute to the onset of diabetes type 1. These are issues that are in need of further research (Ziegler *et al.*, 2003, Knip and Akerblom, 2005).

6.3.3 Sugar/intense sweeteners and type 2 diabetes

A few prospective population studies have investigated the relation between sugared drinks and the development of type 2 diabetes. In the "Nurses' Health Study" in USA from 1991 to 1999 which included 91249 women without diabetes, a 40% increased risk of developing type 2 diabetes was revealed for women with a high consumption of sugar sweetened beverages compared to those who did not have a high consumption (Schulze *et al*., 2004). Data from The European Cancer and Nutrition Study, EPIC, also support this finding. Schulz *et al*. examined 17369 European men and women with a mean follow-up period of 2.2 years. A high energy intake and a diet rich in sugar, was related to weight gain, in particular in the male group (Schulz *et al.*, 2002). In this study, soft drinks included water, juice, soda pop and lemonade.

In the"Women's Health Study" in USA the diets of 38480 post-menopausal women and incidences of diabetes were registered over a six-year period. A high intake of sucrose, lactose, glucose or fructose was not found to increase the risk of developing type 2 diabetes (Janket *et al.*, 2003).

In the "Framingham Offspring Study" in USA including 2834 men and women, no association was found between the overall intake of carbohydrates and the occurrence of insulin resistance. However, a high intake of fibre was shown to give less insulin resistance (McKeown *et al*., 2004). A diet rich in whole grain is low in simple sugar, and has e.g. been documented in prospective studies to decrease weight gain in middle aged women (Liu *et al.*, 2003).

The Nordic Nutrition Recommendations (NNR, 2004) emphasise the importance of a dietary intake of carbohydrates of the complex type and a low intake of simple sugars (<10E%). Such a diet may be classified as having a low glycemic index (GI). It is a matter of debate whether the GI measurement system is a useful tool in practical dietary advice (Kolset, 2003, NCM, 2005).

A potential relation between high intake of sugared drinks and increased risk of type 2 diabetes may be due to an indirect effect caused by extra energy supply from sugar which contributes to overweight, as has been pointed out in the recent review by Malik *et al.* (2006). It is also possible that sugar can have other biological effects that can promote the development of diabetes type 2, such as through increased levels of advanced glycation end-products, increased oxidative stress and promotion of endothelial inflammation (Omsland *et al*., 2006).

Studies of intense sweeteners indicate that these substances may contribute to a reduction of weight if they replace energy-rich food (Raben *et al*., 2002). If intense sweeteners, as sugar-replacements, can contribute to weight reduction and thereby improved insulin sensitivity, it is also possible that they may reduce the risk of type 2 diabetes.

Investigation of the effect of daily administration of sucralose for 3 months on glycemic control was studied in subjects with type 2 diabetes. Subjects aged 31- to 70 years that have had type 2 diabetes for at least one year and managed their diabetes with either insulin or an oral hypoglycaemic agent, were selected. The study was a multicentre, double-blind, placebo controlled,

randomized study, consisting of a 6-week screening phase, a 13-week test phase and a 4-week follow-up phase. Subjects were randomly assigned to receive placebo cellulose capsules (n = 69) or 667 mg encapsulated sucralose (n = 67) daily, where 128 completed the study. Glycated haemoglobin (HbA1c), fasting plasma glucose and fasting serum C-peptide were measured approximately every 2 weeks. For none of the measured parameters there were significant differences between sucralose and placebo groups when compared to baseline. This study demonstrates that sucralose intake for 3 months of 7.5 mg/kg bw/day had no effect on glucose homeostasis in individuals with type 2 diabetes (Lee Grotz *et al*., 2003).

6.3.4 Intense sweeteners and insulin

The question of whether intense sweeteners can induce pancreatic insulin has been raised as an issue. Glucose intake and increase in blood leads to insulin release. This is necessary, as insulin mediates glucose uptake in the important target organs muscle and adipose tissue. Studies on possible insulin release following intake of artificial sweeteners have been addressed in animal studies, experimental cell biological studies and some studies on human subjects.

Insulin levels in blood have not been found to be affected by aspartame or saccharin intake in human subjects (Horwitz *et al*., 1988, Carlson and Shah, 1989) Furthermore, some studies have addressed whether sweet taste in itself would affect insulin release and changes in the hypothalamus (cephalic responses). In short-term experiments (5-70 min), 12 normal weight human subjects ingested sucrose or aspartame. Blood samples were drawn and cephalic responses were recorded. Insulin increase in plasma was only observed after intake of sucrose but not after intake of aspartame (Abdallah *et al.*, 1997). A similar conclusion was reached in a recent study on five human subjects ingesting either glucose, aspartame or malt dextrin. Blood samples were drawn after intake and cephalic responses were recorded using MRI (magnetic resonance imaging). Glucose and malt dextrin intake resulted in insulin increase in the blood. Only glucose intake resulted in cephalic response (Smeets *et al.*, 2005).

In conclusion the results support the notion that glucose is the only sweet tasting substance documented at present to induce insulin release.

6.3.5 Summary of sugar/intense sweeteners from soft drinks/'saft' and diabetes

There are few studies on the association between consumption of sugar sweetened beverages and the risk of developing diabetes, especially diabetes type 1. The few prospective studies available indicate a positive correlation between sugar sweetened beverage consumption and the risk of developing diabetes type 2. However, this may result from the increased risk of weight gain and obesity observed with high consumption of sugared beverages, and may not necessarily be a direct effect of the sugar sweetened beverages.

6.4 Sugar/intense sweeteners from soft drinks, 'saft' and nectar and dental health

Consumption of soft drinks can affect dental health in two ways; in a dental caries process where destruction of the hard tissues of the teeth is due to bacterial acid production, or in a dental erosion process which is a chemical destruction of the hard tissues of the teeth without the presence of bacteria.

6.4.1 Incidence of dental caries

The dental health, expressed as an average number of teeth with caries experience (DMFT; Decayed, Missing or Filled Teeth) among children and adolescents examined/treated by the Norwegian Public Dental Services has clearly improved from 1985 until today, possibly as a result of extended use of fluorides and better dental hygiene. However, in recent years, the improvement has stopped. Figure 3 shows the development of the average number of teeth with caries experience among Norwegians aged 12 and 18 years from 1965 to 2004.

As a result of a change in intervals at which patients are being recalled, it is possible that people with good dental health are examined more seldom, while those with poor dental health are being recalled as often as before. The occurrence of dental caries among those who are under the supervision of the Norwegian Public Dental Services therefore seems to increase, even though the dental health in children and adolescents in general may not have changed. Another explanation is a change in treatment strategy. Not all caries attacks demand a filling of the tooth.

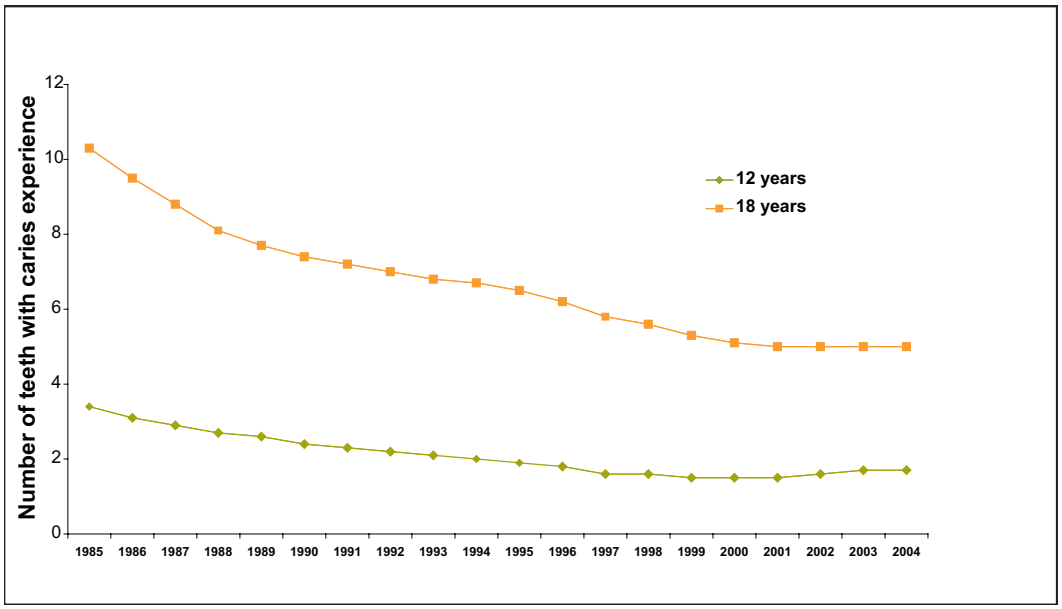


Figure 3. The development of average number of teeth with caries experience among Norwegians aged 12 and 18 from 1965 to 2004 (Ministry of Health and Care Services, 2005)

It is commonly understood that the dental health among children and adolescents in Norway is good. However, dental caries is still a widespread disease, and four out of five 18-year-olds have caries lesions that require treatment (Ministry of Health and Care Services, 2005).

6.4.2 Mechanism of dental caries

Dental plaque, a bacterial biofilm, forms rapidly on tooth surfaces. If left undisturbed the plaque will mature and develop the capacity to convert fermentable carbohydrates into acids. This leads to a drop in plaque pH levels. At neutral pH, there is a natural balance between the main enamel mineral surface ions (calcium, phosphate and hydroxyl) and those of the plaque/saliva in contact with the tooth. When the pH levels fluctuate, the minerals migrate in and out of the surface enamel. When the pH falls below approximately 5.5, the mineral balance favours demineralisation and ions are lost from the enamel surface. This occurs on the tooth root surface already at approximately pH 6.5. When the pH remains lowered, or decreases further due to further acid production, the demineralisation will eventually lead to cavity formation (i.e. a caries lesion is formed). This process can be prevented through good dental hygiene and fluoride supplementation. Fluoride acts in several ways to strengthen the enamel surface against acid attack.

Most of the sugars and other fermentable dietary carbohydrates are metabolised by oral micro-organisms, and initiate and enhance the development of caries in the following ways:

- bacteria form sticky extracellular polymers enabling the bacteria to adhere to the tooth and to each other, supporting a colonization of the tooth surface
- bacteria form extracellular and intracellular storage polysaccharides for use at times of low sugar availability
- most importantly, bacteria use carbohydrates in a glycolic pathway, resulting in the production of organic acids

With ample access to sugar, dental plaque will become denser, and will thus be able to stifle the diffusion of acid away from the tooth surface. Dense plaque prevents the saliva from neutralising bacterial acids and rinsing away the sugars and the sugars remain in the oral cavity over longer periods of time. The frequency of meals containing fermentable carbohydrates is often directly related to overall carbohydrate consumption. Retention of carbohydrates is dependent on several factors such as type and consistency. Sugar in a fluid form is less cariogenic than in a solid form, because the fluid form is retained for shorter periods of time compared to a solid, more retentive form. However, the lesser cariogenic effect of fluid sugar will be counteracted when there is a pattern of high frequency drinking. Therefore, the goal should be to reduce the total quantity as well as the frequency of sugar intake (Moynihan *et al*., 2003, Moynihan and Lindström, 2005)

Sucrose has, for a long time, been assumed to be in a category of its own because it is the substrate of the *Streptococcus mutans'* production of the extracellular polysaccharides fructan and glucan, via the enzyme glucosyl transferanse (Gtf). These polysaccharides are first and foremost responsible for the formation and stickiness of the plaque, which enables bacteria to attach themselves to the dental surface. However, it is presently known that sucrose is not the only caries-promoting sugar type. Other factors are equally important, such as the consistency and frequency of the intake. Thus, it would be a mistake to assume that replacing sucrose with other kinds of sugars will lead to significantly lower caries incidence (Zero, 2004).

6.4.3 Relationship between sugar consumption, intense sweeteners and dental caries

Woodward and Walker found a clear linear relationship between total sugar intake (total intake per capitum) and caries calculated from data in 90 countries (Woodward and Walker, 1994).

However, more recent data indicate that the relationship between sugar consumption and dental caries is not as strong as it was in the prefluoride era. In industrialised countries where fluoride exposure has become the norm through the use of fluoride dentifrices, and/or water/salt fluoridation and other vehicles of fluoride delivery, the relationship between sugar and caries has been more difficult to demonstrate. This has led some authors to conclude that recommendations to restrict sugar intake may no longer be necessary (König, 2000, van Loveren, 2000). Clearly, fluoride has raised the threshold at which the caries process will progress to frank cavitations, and a higher cariogenic diet can be tolerated before caries occurs in many individuals. However, fluoride has its limits, and caries remains a serious problem for economically disadvantaged individuals and new immigrants in many highly industrialised countries. It continues to be a discussion about the nature of the relationship between sugar intake and caries and whether there is a safe level of sugar intake. Newbrun (1982) proposed that the relationship best can be described by an S-shaped curve based on animal studies, and speculated that the S-shaped curve may have moved to the right in the postfluoride era (Figure 4) (Newbrun, 1982). Woodward and Walker (1994) reported that the relationship is linear based on their analysis of sugar consumption in 90 countries. In individuals with good oral hygiene and regular fluoride exposure, higher levels of sugar intake may be tolerated before caries occurs (Zero, 2004).

Figure 4. Proposed relationships between sugar intake (daily sucrose) and caries score (adapted from Lussi et al., 2004)

a) S-shaped relationship in the prefluoride era (Newbrun, 1982).
b) S-shaped relationship shifted to the right in postfluoride era (Newbrun, 1982).
c) Linear relationship calculated from data in 90 countries (Woodward and Walker, 1994).
d) Individuals with good oral hygiene and regular fluoride exposure (Zero, 2004) conjecture.

Intense sweeteners cannot be fermented by bacteria in the mouth and do not produce acids that erode tooth enamel. They cannot, therefore, cause dental decay.

6.4.4 Incidence of dental erosion

There is some evidence that the presence of erosion is growing steadily. Because of different scoring systems, samples and examiners, it is difficult to compare and judge the outcome of different studies. There are no recent Norwegian studies on dental erosion, but a study has recently been performed in Iceland.

A representative sample of 2254 Icelandic children in first, seventh and tenth grade (approximately 6-year-olds, 12-year-olds and 15-year-olds, respectively) was examined. The results from this national representative sample of Icelandic children were that 30% of the 15-year-olds showed signs of dental erosion and almost 15% of the 12-year-olds. Dental erosion was found to be almost twice as frequent among boys as in girls. This survey indicated an even higher prevalence of erosion than earlier reported in regional surveys of similar age groups (Poster: Augustdottir *et al*., 2006).

6.4.5 Mechanism of dental erosion

Defined as a surface dissolution of dental hard tissues by acids without the involvement of micro-organisms, dental erosion may be caused by a series of extrinsic and intrinsic factors. Extrinsic factors largely include the consumption of acidic foods and carbonated beverages, sports drinks, wines, citrus fruits and, to a lesser degree, occupational exposure to acidic environments. The most common intrinsic factors include chronic gastro-intestinal disorders such as gastro-

oesophageal reflux, as well as health conditions such as anorexia and bulimia where regurgitation and frequent vomiting are common (Zero and Lussi, 2005).

The erosive activity of citric- and phosphoric acid and other acids that are used as ingredients in beverages and foods, has been demonstrated in many *in vitro*, *in situ* and *in vivo* studies (Zero, 1996). Further, a series of studies indicates that the erosive potential of an acidic drink is not entirely dependent on its pH, but is also strongly affected by its titratable acid content (buffering capacity) and by the calcium-chelating properties of the food and beverages, as they efficiently bind released calcium. The greater the buffering capacity of the drink, the longer it will take for saliva to neutralise the acid (Lussi *et al.*, 2004, Zero and Lussi, 2005).

A thick pellicle and accumulation of plaque have a preventative effect on the diffusion of acidic chemicals, and thus a protective effect. The buffer capacity of foods and drinks has been shown to be more significant than pH. If the food or drink contains calcium (yoghurt, sour milk) or phosphates (some cola drinks), the erosion impact is lower even if the pH is low (Larsen and Nyvad, 1999).

There is a considerable variation in progression between patients with a small subgroup having a large degree of erosion. Erosion can be prevented by changing the dietary composition and consumption habits. Acidic fluoride gel has a preventative effect, and tooth brushing must be avoided immediately after consumption of erosive foods and drinks. Meals should be rounded off with something that stimulates saliva production, such as cheese or sugar-free chewing gum (Dahl, 2002). The relationship between acid levels (pH) at the tooth surface and time following consumption of foods and drinks is shown in what is known as the Stephan Curve.

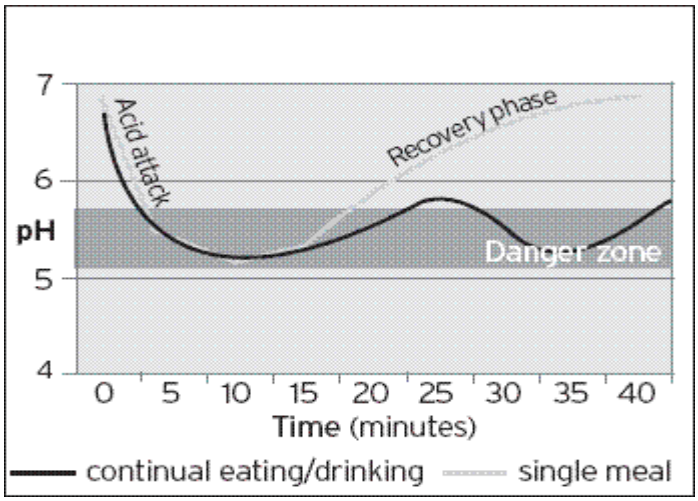


Figure 5. The Stephan Curve shows an increase in acid accumulation at the tooth surface (a drop in pH) immediately after we eat or drink something. After swallowing, saliva dilutes what remains in the mouth, reducing the potential for tooth surface damage. It takes approximately 20 minutes for the saliva to do its job of diluting and washing away the erosive liquid in contact with the tooth surface until the pH exceeds 5.5 (Stephan, 1940)

6.4.6 Acidity range of the most sold soft drinks, 'saft' and nectar

The pH range in the most sold soft drinks, 'saft' and nectar in Norway are shown in Table 5. All of them have pH far below the critical pH for dissolution of the hard tissues of the teeth, and there is no significant difference in pH in sugared soft drinks, 'saft' and nectar compared to the drinks with intense sweeteners. The most common acid in these products are citric acid, only the Cola drinks contain phosphoric acid.

Table 5. Acidity range in the most sold soft drinks, 'saft' and nectar in Norway

Sugar sweetened drinks	pH range
Carbonated soft drinks	2.3 – 3.5
'Saft'	2.8 – 3.2
Ice tea	3.1 – 3.6
Nectar	3.1

Drinks with intense sweeteners	pH range
Carbonated soft drinks	2.7 – 3.5
'Saft'	3.0 – 3.1

6.4.5 Summary of sugar/intense sweeteners from soft drinks, 'saft' and nectar and dental health

Sugar sweetened soft drinks, 'saft' and nectar can affect dental health in two ways: through dental caries and dental erosion. The association between sugar intake and dental caries is well documented and relatively linear. In individuals with good oral hygiene and regular fluoride exposure, higher levels of sugar intake may be tolerated before caries occurs. As there are no differences in pH and acid content between sugar sweetened soft drinks, 'saft' and nectar and the drinks with intense sweeteners, a reduction of the sugar content will not affect the incidence of dental erosion, but will most probably reduce the incidence of dental caries. From a dental health aspect it is strongly recommended to reduce the intake of acidic and sugar sweetened drinks.

7 Risk assessment method descriptions

International bodies as the Scientific Committee on Food (SCF), the European Food Safety Authority (EFSA) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) have established values for the acceptable daily intake (ADI) of intense sweeteners and the preservative benzoic acid. There is, however, no comparable level set for mono- or disaccharides, and there is no literature on the risk characterisation (dose-response studies) for sucrose. The most important health hazards (overweight, diabetes, dental health) associated with a high intake of sugars from soft drinks, 'saft' and nectar are discussed in Chapter 6, while the considerations on sugars in Chapter 8 are an assessment of added sugars in general, compared with the Nordic recommendations for intake of sugars.

All health hazards associated with the allocation of ADI for the intense sweeteners and benzoic acid are included as part of the risk assessment of these substances.

7.1 Authorisation of food additives

Food additives, including intense sweeteners and benzoic acid, have to be authorised by the authorities before they can be placed on the market. Intense sweeteners and benzoic acid can only be authorised provided that a reasonable technological need can be demonstrated, and that they do not represent hazard to the consumer health at the level of use proposed, and that they do not mislead the consumer.

In order to ensure that a food additive does not represent a hazard to the health of the consumer, the potential risk of the specified uses of the food additive is assessed before authorisation. Guidance on the authorisation is given by the EC Commission and EFSA. The applier must provide the required documentation, which is then assessed by EFSA. The assessment includes an intake assessment based on proposed use and dietary intake studies. The object of the intake assessment performed prior to the potential authorisation is to evaluate whether the intake of the proposed food additive will exceed the ADI value. A major change in the dietary pattern may have substantial effect on the intake, and may as a worst case invalidate the conditions of the authorisation of the food additive.

Sugars as ingredients are not subjected to specific legislation or authorisation. Mono- or disaccharides (e.g. fructose and sucrose) have therefore not been risk assessed in relation to their use as sole ingredients, nor as ingredients in specific foods or drinks. Health consequences from sugar in soft drinks are described in Chapter 6.

7.1.1 Derivation of the ADI

The concept of ADI for humans was originally developed between 1956 and 1962 by JECFA and defined as "an estimate of the amount of a food additive, expressed on a body weight basis that can be ingested daily over a lifetime without appreciable health risk". ADI is now also used in the evaluation of pesticides. A similar concept called the tolerable daily (or weekly) intake (TDI (or TWI)) is applied to contaminants in food.

Results from studies in humans, experimental animals and *in vitro* are used in deriving the ADI. Studies on acute toxicity, sub-acute toxicity (28-90 days), chronic toxicity and carcinogenicity should be included in a standard toxicity data set. Studies on metabolism and kinetics as well as short-term *in vitro* studies of mutagenicity/clastogenicity are also required. Data on metabolism and kinetics should preferably be from humans.

From the toxicity data set a no observed adverse effect level (NOAEL) is determined from the most sensitive study in the most sensitive species tested. The NOAEL is the highest dose level producing no detectable adverse alterations of morphology, functional capacity, growth, development or life-span.

The ADI is established from the NOAEL by dividing it by a safety factor. Usually a safety factor of 100 is used by default, subdivided in a factor of 10 for interspecies differences (most sensitive experimental animal species to humans) and 10 for interindividual differences in humans, where each factor of 10 should allow for differences in toxicokinetics and toxicodynamics. This may be modified when adequate human data are available or based on comparative pharmacokinetic/dynamic data. Safety factors larger than 100 could also be applied if it is found appropriate to establish a temporary ADI from an inadequate data set (ILSI, 1997). A small exceedance of the ADI will therefore reduce this safety factor and not necessarily cause health concern.

7.1.2 Applicability of the ADI to infants and children

Exposure of children to food additives has for a long time been an important part of the discussion on food additive safety for human health. It has been suggested that the use of food additives represents a higher risk for infants and children than for adults and that special ADIs should be established for these age groups. Another argument has been that infants and children in general are more susceptible to the effects of chemicals than adults, because they have a higher food intake than adults on a per kg body weight basis.

According to the original premises defined by JECFA and SCF, the above-mentioned default safety factor of 100 is supposed to cover differences in species sensitivity, synergistic or antagonistic actions among food additives and other components of food, the heterogenecity of the exposed human population with regard to pregnancy, physiological status and nutrition, age differences between exposed individuals and the variability in susceptibility with age to the potential adverse effects of an ingested toxic substance.

The applicability of the ADI to infants and children has been discussed in a consensus report from a workshop organised by the ILSI Europe Acceptable Daily Intake Task Force in January 1997 (ILSI, 1997).

Examination of the differences in toxicokinetics between infants or children and adults have shown that the elimination of xenobiotics was either similar to or in many cases higher in children than in adults. Children will therefore frequently have lower body burdens than adults for the same daily intake of a chemical, when expressed on a body weight basis. Based on this, the ILSI working group concluded that an increased safety factor was not required for differences in toxicokinetics between post-suckling infants or children and adults. As first stated by JECFA in 1987, ILSI emphasised that this conclusion does not apply to infants before the age of 12 weeks during which period the maturation of the xenobiotic metabolising systems and elimination processes take place. They also pointed out that another argument for the ADI not being applicable to infants below 12 weeks of age is that the usual toxicological test battery does not mimic the human situation with ingestion of infant formula.

Overall, the ILSI workshop recommended that special safety factors for infants and children should not be used, and consequently special ADIs should not be established (ILSI, 1997).

7.2 Methods for intake estimations

7.2.1 Consumption data

The following national representative dietary surveys are used in the exposure assessments:

- **Adults**; Norkost 1997 (Johansson and Solvoll, 1999), Norkost is based on a quantitative frequency questionnaire that was answered by 1291 males and 1381 females aged 16-79 years.

- **9- and 13-year-old children/adolescents**; Ungkost 2000 (Øverby and Andersen, 2002). Ungkost 2000 is based on a 4-day food consumption registration, where portions should be assigned according to an illustrative book with different food portion sizes. (9-year-olds: 411 females and 404 males, 13-year-olds: 517 females and 492 males).
- **4-year-old children;** Ungkost 2000 (Pollestad *et al.,* 2002). Ungkost 2000 is based on a 4-day food consumption registration (391 children), where portions should be assigned according to an illustrative book with different food portion sizes.
- **2-year-old children;** Småbarnskost (Lande and Andersen, 2005b). Småbarnskost is based on a semi-quantitative food frequency questionnaire (FFQ) answered by 868 males and 852 females.
- **1-year-old children;** Spedkost (Lande and Andersen, 2005a). Spedkost is based on a semi-quantitative FFQ answered by 1022 males and 910 females. However, only those children who were not breastfed (674 males and 557 females) were included in the exposure assessment in this report.
- **Omnibus survey;** Intense sweeteners. In order to estimate the intake of intense sweeteners a dietary survey among adults was carried out in 1997 (Bergsten, 1998). The survey included 1375 individuals aged 16-80 years, 677 males and 698 females. The participants answered a quantitative FFQ which only included products sweetened with intense sweeteners.

7.2.1.1 Methodological challenges

Data on food consumption in Norway are available at three different levels; the national food supply, household surveys and dietary surveys (Directorate for Health and Social Affairs, 2005a). In the present report, the risk assessment has been based on data from national representative dietary surveys. In this type of surveys, information about food consumption among individuals is collected using a dietary assessment method. Presently, there is no method available without error to measure dietary exposure. Therefore, evaluation of the dietary assessment tools should be performed, and results from these evaluation studies should be kept in mind in interpretation of results from the surveys.

In Norkost, a 180-item quantitative FFQ was used. The FFQ has been validated in several studies and was found to give a valid intake on a group level (Andersen *et al*., 1999). No significant difference in average intake of added sugar was observed between the FFQ and 14 days weighed records among men (Andersen *et al*., 1999). Spearman's rank correlation coefficients[8] between added sugar from the FFQ and 14 days weighed records was 0.66 for men (n = 125) (Andersen *et al*., 1999) and 0.61 among elderly women (n = 31) (Nes *et al*.,1992).

In Ungkost 2000, a 4-day food diary was used. The food diary has been found to underestimate energy intake among both 9- and 13-year-olds (n = 51 and n = 72) (Andersen *et al*., 2005b, Lillegaard *et al*., 2005). However, Lillegaard *et al.* (2005) did not observe a significant difference in consumption of added sugar (p = 0.05) and soft drinks with sugar (p = 0.09) when comparing individuals who underreported their food consumption with those that did not. There was no significant difference between average (median) intake of added sugar and E% from sugar when comparing 4-days food diary with 4-days weighed record among 9-year-olds (n = 100) (Lillegaard *et al*., 2007). Spearman's rank correlation coefficients between intake of added sugar from the diary and weighed records was 0.37 (n = 45) and 0.51 (n = 55) among girls and boys, respectively (Lillegaard *et al*., 2007). The figures for soft drinks with sugar were 0.31 and 0.24 for girls and boys, respectively (unpublished data).

In Spedkost (1-year-olds) and Småbarnskost (2-year-olds), two similar FFQ's were used. Both questionnaires were found to overestimate energy intake (Andersen *et al*., 2003, Lande and Andersen, 2005b). The average (median) percentages of energy intake from added sugar were not significantly different between the FFQ and 7-days weighed record among 1-year-olds,

8 Spearman's rank correlation coefficient is used as a linear relationship between two sets of ranked data, that is it measures how tightly ranked data cluster around a straight line, see section 4.14

while the FFQ among 2-year-olds seems to underreport percentage of energy intake from added sugar. There was no significant difference in average (median) consumption of sugar sweetened soft drinks between the FFQ and weighed records among the 1-year-olds. Spearman's rank correlation coefficients for soft drinks with sugar were 0.28 and 0.51 among 1- and 2-year-olds, respectively.

In summary, the data from the validation studies conducted with the methods used in Norkost, Ungkost, Sped- og Småbarnskost indicate that the data on group level (mean value) for percentage of energy from added sugar and consumption of soft drinks with sugar are relatively valid. The capability to rank individuals according to intake is good among adults but seems to vary among children. The consumption data at the 95th percentile will often be less accurate than the average value because it is based on a smaller sample size. Moreover the over- and underreporting of energy intake identified among the youngest children (1- and 2-year-olds) and among 9- and 13-year-olds, respectively, may have an impact on the validity of the 95th percentile. The size of this problem is not quantified

7.2.2 Food composition data

In order to determine the concentration of benzoic acid, aspartame, acesulfame K, cyclamate, saccharine and sugar in soft drinks, 'saft' and nectar a questionnaire was sent out to all manufacturers and importers of drinks. Beside questions on the content of each substance, the questionnaire addressed the pH, type of acid and annual sales figures (2004) for each product. Table 6 shows the number of samples for each type of drink which are included in the exposure assessments. Annex 2 shows the concentrations of sugar, intense sweeteners and benzoic acid in these drinks.

Table 6. Number of samples of studied drinks

Food	Included products	Number of samples
Soda with sugar	Soft drinks with or without gas (CO_2), ice tea, non-alcoholic cider, tonic, russian water, sport drinks	83
Soda with intense sweeteners	Soft drinks, ice tea, non-alcoholic cider energy reduced or without added sugar	28
Battery	Battery	1
'Saft' 1:4		30
Blackberry 'saft'	Blackberry 'saft'	3
Orange flavoured 'saft'[1]	Orange flavoured 'saft'	5
'Saft', energy-reduced	Energy reduced 'saft' and concentrates	16
Apple nectar	Apple nectar only	1
Concentrated blackberry 'saft'[2]	Blackberry 'saft' for cooking	*3*
Concentrated 'saft'[2]	Concentrated 'saft' for cooking purposes	3

1 Made from oranges
2 Only for cooking

The dietary surveys do not distinguish between energy reduced 'saft' and energy reduced concentrates, but nominate all as 'saft' light. In the calculations all energy reduced concentrates; 'saft' and other similar drinks have been categorised as 'saft' light. In the intake estimates this has no relevance for the results.

For benzoic acid, the content in other foods than soft drinks, 'saft' and nectar is based on either analytical values, information from food manufacturers and in a few cases the upper authorised use level in food (Bergsten, 2000). Annex 2 shows the concentration of benzoic acid in other foods included in the exposure assessment of benzoic acid.

For intense sweeteners, the content in other foods than soft drinks, 'saft' and nectar is based on analytical values (Bergsten, 1998).

For sugar, the content in other foods than soft drinks, 'saft' and nectar is based on data from the Norwegian Food Composition Database (the figures submitted from the producers on sugar in soft drinks were similar to those in the Norwegian Food Composition Database, and those in the database were therefore used).

7.2.3 Exposure assessment

In the intake calculations of added sugar, intense sweeteners and benzoic acid a method using the distribution of consumption values has been chosen. Consumption estimates for each food were multiplied with the corresponding concentration estimate and totalled for each individual. The resulting distribution of the total daily intake (expressed as the total intake/kg body weight/person) has been used to derive the average daily intake of the food additives in question (Figure 6). For added sugar the distribution of the total daily intake is expressed as g/person/day.

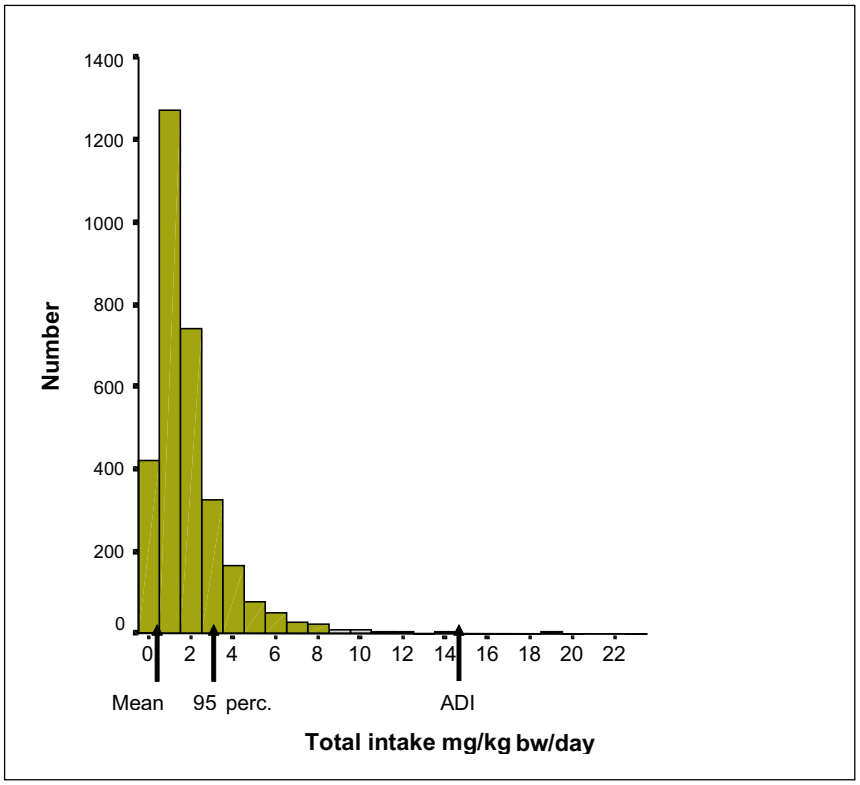


Figure 6. An example of a distribution of the total intake of a food additive

It has not been possible to use the detailed information obtained by determination of the levels of the substances (including sugar) in specific food brands. The reason for this is that the dietary surveys only give information of consumption of generic foods, not product brands. Instead, a weighted average value of the substances in the different drinks included has been used, for instance average content of benzoic acid in all drinks sweetened with sugar.

The weighted average values for the content of added sugar and the food additives aspartame, acesulfame K, cyclamate, saccharin and benzoic acid in drinks were calculated based on information on actual content of sugar and food additives and sales volumes provided by the food manufacturers. An example is given in Annex 1.

The calculated intakes of nutrients, such as sugar, are usually expressed as the mean or the median values of intake. Since high consumers are of special interest in dietary exposure assessments of food additives and contaminants, it is especially important to identify the groups with high intake values. The results presented in this report therefore show high values for consumption of the foods and high intake of the substances, as well as the mean and median values. An upper

percentile has been commonly used instead of the maximum food consumption and concentration values. In this report "high consumers" refer to the 95th percentile, both as regard to intake of added sugar and consumption of soft drinks, 'saft' and nectar.

The word "consumption" refers to the amount of a food or a group of food a person has eaten or drunk, while the word "intake" refers to the amount of substance that the person has ingested.

In the calculations, a distribution of each participant's intake of the intense sweeteners and benzoic acids from each food/food group has been derived. For instance, each participant's consumption of soft drinks, 'saft' and nectar was multiplied with its weighted average content of benzoic acid. Based on the distribution of the consumption of soft drinks, 'saft' and nectar, mean, median and high (95th percentile) intakes of benzoic acid were derived.

The amount of a substance estimated as reported by the participants in the dietary surveys has been based on only the persons who actually consumed the food or drinks (consumers only). If all the participants in the dietary survey are included in the calculation, the intake of a substance on a group level will be distributed also among those who have not had any intake of the substance. This may result in underestimation of intake among those who actually consume the foods.

7.2.4 Estimations/scenarios

The daily intake of sugar, intense sweeteners and benzoic acid were estimated according to the following three situations:

a) The current situation according to national representative dietary surveys is based on the actual content of intense sweeteners and benzoic acid in food and drinks. The calculations on sugar are based on the content of added sugar according to The Norwegian Food Composition Database. It is important to have in mind that the current situation was based on dietary intake data from the period 1997-2001. The intake of sugar sweetened soft drinks and 'saft' may have changed during the last 5 years.
b) The assumption that 50% of all soft drinks, 'saft' and nectar consumed are sweetened with intense sweeteners and 50% are sweetened with sugar (50% scenario). In this scenario it was assumed that all soft drinks, 'saft' and nectar, including the sugar-free ones, contained half the amount of sugar compared to the regular drinks. The intake of added sugar from other foods and drinks was based on the actual content according to the Norwegian Food Composition Database. The intake of benzoic acid and intense sweeteners from other foods than soft drinks, 'saft' and nectar was based on the actual content, as used in the current situation.
c) The assumption that 100% of all soft drinks, 'saft' and nectar consumed are sweetened with intense sweeteners (100% scenario). The intake from foods was based on the actual content, as used in the current situation.

Energy from added sugar is estimated in the three situations. For the 50% and 100% scenarios, it was necessary to adjust energy intake, due to lower consumption of sugar, before estimation of energy from added sugar.

In the 100% scenario, adjusted energy intake from added sugar was calculated by subtracting the energy intake from added sugar in all soft drinks, 'saft' and nectar from the energy intake from added sugars from all sources.

Adjusted total energy intake in the 100% scenario was calculated by subtracting the energy from added sugars in all soft drinks, 'saft' and nectar from the original total energy intake.

In the 50% scenario, adjusted energy intake from added sugar was calculated by subtracting the energy intake from added sugar in all soft drinks, 'saft' and nectar from the energy intake from

added sugar from all sources, and then adding energy intake from a calculated concentration of added sugar in soft drinks, 'saft' and nectar containing 50% sugar and 50% intense sweeteners.

Adjusted total energy intake in the 50% scenario was calculated by subtracting the energy from a calculated concentration of added sugar in soft drinks, 'saft' and nectar containing 50% sugar and 50% intense sweeteners from the original total energy intake.

A 100% scenario example:

Current situation
Total energy intake: 7800 kJ
Energy intake from added sugar: 470 kJ
E% from added sugar: 6E%
Sugar in all soft drinks, 'saft' and nectar: 8 grams
Energy intake from all soft drinks, 'saft' and nectar: 8x17 kJ = 136 kJ

Adjusted energy intake in the 100% scenario
Adjusted total energy intake: 7800 kJ – 136 kJ = 7664 kJ
Adjusted intake from added sugar: 470 kJ – 136 kJ = 334 kJ
E% from added sugar in the 100% scenario: 4E%

7.2.5 Consumption of studied drinks

Figure 7a and 7b show the mean and median daily consumption of drinks among the different age groups and Figure 7c shows the consumption at the 95th percentile. Only data on nectar sweetened with sugars were included in the dietary surveys. Annex 3 shows the absolute values of consumption of soft drinks, 'saft' and nectar both with sugar and with intense sweeteners in the current situation and 100% scenario.

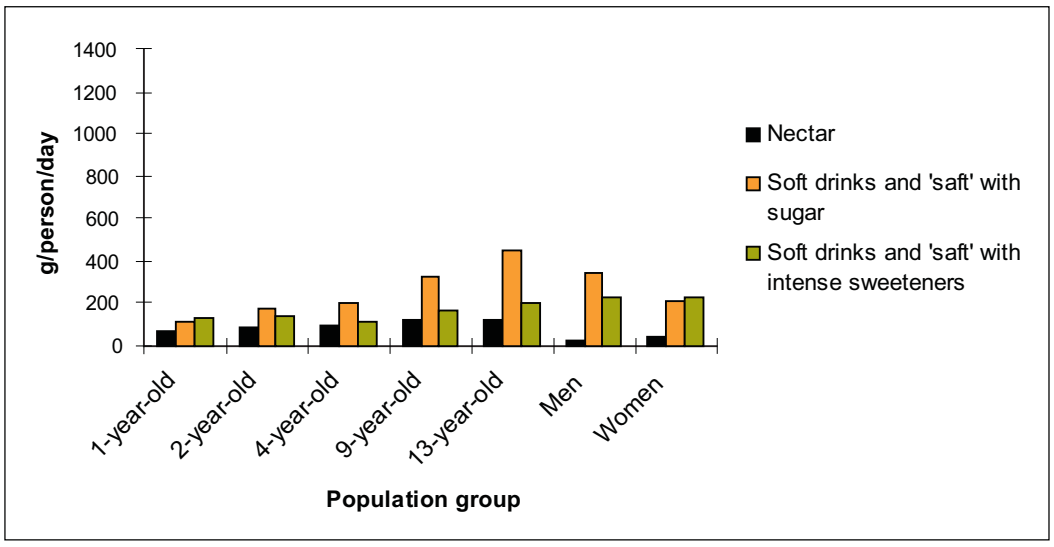


Figure 7a. Mean daily consumption of drinks among consumers only at current level

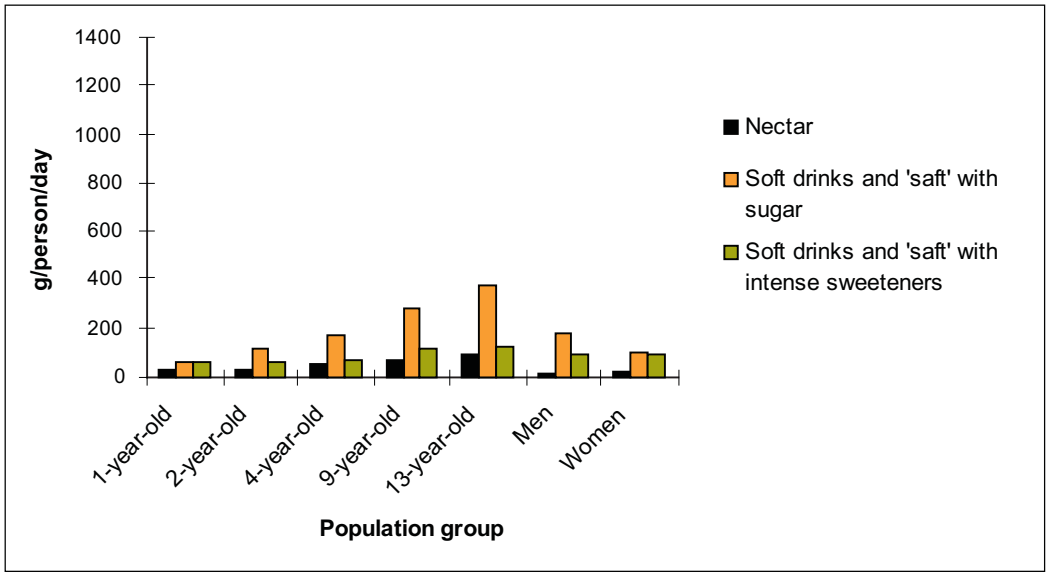


Figure 7b. Median daily consumption of drinks among consumers only at current level

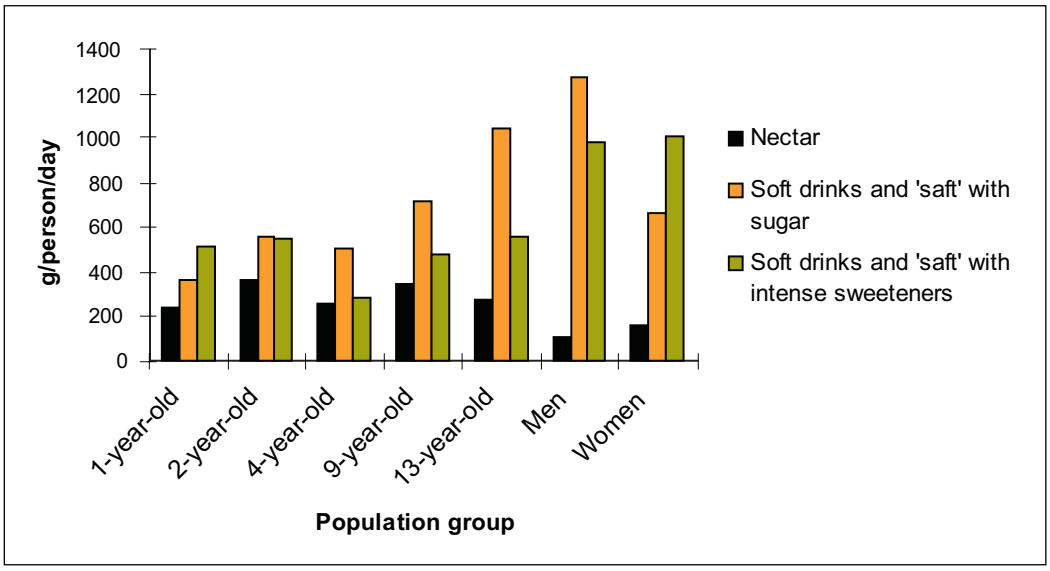


Figure 7c. Data on 95th percentile daily consumption of drinks among consumers only at current level

High consumption of sugar sweetened soft drinks and 'saft' range from approximately half a litre or less per day among children up to 4-year-old to more than one litre among 13-year-olds and men.

High consumption of soft drinks and 'saft' with intense sweeteners range from approximately half a litre or less per day among children and adolescents, and up to one litre among men and women.

8 Risk assessment of intake of added sugar

8.1 Hazard characterisation of added sugar

When evaluating the risk of sugar sweetened drinks, there is no upper level of acceptable intake. However, as Table 7 shows, consumption of sugar sweetened soft drinks is the most important single source of the total consumption of added sugar among children and adolescents (Pollestad *et al.,* 2002, Øverby and Andersen, 2002, Lande and Andersen 2005 a,b). The health risk from consumption of sugar sweetened soft drinks could be evaluated comparing the percentage of energy from added sugar with the Nordic Nutrition Recommendations on added sugar (maximum 10% of the energy should derive from added sugar).

Table 7. The proportion of sugar from the different food groups in relation to the total intake of added sugar

Foods/drinks	1 year	2 year	4 year	9 year	13 year
Sugar sweetened soft drinks and 'saft'	26	42	33	38	44
Yoghurt	20	19	11	5	5
Sugar, sweets	3	13	22	28	27
Jam	18	11	8	5	4
Cakes, biscuits	4	5	11	9	8
Industry produced porridge	17	2	-	-	-

Health consequences from intake of sugar in general have been thoroughly described in the Danish report "Sukkers sundhedsmæssige betydning" ("The Health Importance of Sugars") (Danish Nutrition Council, 2003). The Danish report has the same conclusions regarding sugars from beverages as concluded in chapter 6 in this report. Other conclusions in the Danish report not related to beverage consumption or not discussed in the present report are quoted below:

"There is no association between a high consumption of added sugars and the risk of developing diabetes. A diet, which causes high increases in the level of blood glucose and has a low content of dietary fibres, seems to increase the risk of developing type 2 diabetes. Diabetics can consume the same amount of added sugars as the rest of the population (maximum 10E%), on the condition that it is part of a healthy diet rich in dietary fibres and foods causing low increases in the level of blood glucose.

The effect of a high consumption of added sugars on the risk of developing cardiovascular diseases has not been examined directly. However, a few studies on risk factors for development of cardiovascular diseases have been performed. A high consumption of added sugars seems to cause unfavourable changes in the blood levels of HDL cholesterol and triglyceride.

An association between a high consumption of added sugars and cancer has not been documented. However, some studies suggest that it may influence the risk of developing colon cancer, but further investigations are required in order to clarify this matter.

It is not possible to confirm or reject a hypothesised relation between a high consumption of added sugars and bone mineralization, infections, or children's growth. An effect of added sugars on behaviour and learning has not been documented, when it is consumed as part of a nutritionally sufficient diet. Allergy against sucrose has not been documented.

The literature overview and conclusions of the present report support the significance of avoiding a high consumption of added sugars. Eating sugar and sweets may provide pleasure, but no positive effects on health have been documented. Added sugars do not provide essential nutrients and there is basis for the assertion that a high consumption of added sugars has negative consequences on health. The recommendation that the consumption of added sugars should not exceed 10E% is supported."

According to the latest Nordic and Norwegian recommendations for nutrition and physical activity, which are used as guidelines for a healthy diet, refined sugars[9] should not account for more than 10% of total energy intake (NNR, 2004, Directorate for Health and Social Affairs, 2005b). A main reason for recommending an upper limit of 10E% from added sugar is that sugars only provide energy and no nutrients, and this tends to decrease the nutrient density of the diet. The association between sugar consumption and dental caries has also been an important argument. In the latest edition of the Norwegian recommendations a limitation in sugar intake is also recommended especially for children and adults with low energy intakes. It is further stated in these recommendations that a limitation in the intake of sugar sweetened drinks might be of importance in order to prevent overweight (Directorate for Health and Social Affairs, 2005b).

The World Health Organisation (WHO) recommends that the amount of "free sugars" constitute less than 10% of the overall energy intake. "Free sugars" refer to all mono- and disaccharides that are added to food, as well as naturally occurring sugars found in honey, syrups and fruit juices (WHO, 2003). This recommendation is based on the fact that free sugars threaten the nutrient quality of the diet by providing energy without specific nutrients. WHO also considered that restriction of free sugars was likely to contribute to reducing the risk of unhealthy weight gain, noting that (WHO, 2003):

- Free sugars contribute to the overall energy density of diet.
- Free sugars promote a positive energy balance. Research in human volunteers demonstrates increased total energy intake in acute and short-term studies when the energy density of the diet is increased, whether by fat or free sugars.
- Diets that are limited in free sugars have shown to reduce total energy intake and induce weight loss.
- Drinks that are rich in free sugars increase overall energy intake by reducing appetite control (see section 6.2.3.4).

8.2 Exposure assessment of added sugar

The calculated exposure to added sugar was based on actual consumption data and The Norwegian Food Composition Table. Consumption data were taken from Norwegian dietary surveys among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

Each of the following tables show the estimated mean daily intake, median daily intake and the daily intake at the 95th percentile.

8.2.1 Exposure to added sugar at the current level

The estimated total intakes of added sugar at the current level are shown in Table 8. Mean intake increased with age among children and adolescents. Adults had a lower total intake than the 9- and 13-year-olds. The highest 95th percentiles were estimated for the 13-year-olds and the men with an intake at 185 and 182 g/day, respectively. The lowest 95th percentile was found for the 1-year-olds.

9 Refined sugars include sucrose, fructose, glucose, starch hydrolysates (glucose syrup, high-fructose syrup) and other isolated sugar preparations such as food components used as such or added during food preparation and manufacturing.

Table 8. Total intake of added sugar at the current level

	Mean (g/person/day)	Median (g/person/day)	95th percentile (g/person/day)
1-year-old	32	28	71
2-year-old	42	36	91
4-year-old	56	53	98
9-year-old	80	77	142
13-year-old	95	86	185
Men	66	49	182
Women	46	35	113

Table 9 shows percentage of energy (E%) deriving from added sugar at current level for different age groups. Mean E% deriving from added sugar increased with age among children and adolescents. Adults have a lower mean E% from added sugar than the 2-, 4-, 9- and 13-year-olds, and men have an E% similar to that of the 1-year-olds. The 13-year-olds have the highest mean E% from added sugar. Energy from added sugar in this age group represents 19% of the total energy intake. Women have the lowest mean E% from added sugar which represents 9E% of the total energy. The 13-year-olds and the 9-year-olds have the highest 95th percentile at 31 and 27E%, respectively. Among the 4-, 9- and 13-year-olds more than 85% received more energy from added sugar than the recommended maximum level of 10E%. Among the 1- and 2-year-olds, 43% and 56% respectively, had more than 10E% from added sugar.

Table 9. Percent of energy (E%) from added sugar at the current level

	Mean	Median	95th percentile	Proportion (%) with E%>10%	Proportion (%) with E%>15%
1-year-old	10	9	21	43	16
2-year-old	12	11	23	56	24
4-year-old	15	15	25	86	49
9-year-old	17	17	27	87	61
13-year-old	19	18	31	89	68
Men	10	8	21	38	14
Women	9	8	19	34	12

8.2.2 Exposure to added sugar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (50% scenario)

The estimated total intakes of added sugar in the 50% scenario are shown in Table 10. Mean intake increased with age among children and adolescents. The highest 95th percentiles were estimated for the 13-years-old and the adult men with an intake at 143 and 140 g/day respectively. The lowest 95th percentile was found for the 1-year-olds.

Table 10. Total intake of added sugar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

	Mean (g/person/day)	Median (g/person/day)	95th percentile (g/person/day)
1-year-old	30	26	63
2-year-old	36	32	73
4-year-old	47	44	82
9-year-old	66	65	116
13-year-old	76	70	143
Men	56	45	140
Women	43	34	101

Table 11 shows E% deriving from added sugar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners for different age groups. Mean E% deriving from added sugar increased with age among children and adolescents. Adults have a lower mean E% than the 2-, 4-, 9- and 13-year-olds, and women have an E% at the same level as the 1-year-olds. The 13-year-olds have the highest mean E% from added sugar. Energy from added sugar in this age group represents 15E% of the total energy intake. Men have the lowest mean E% from added sugar which represents 8E% of the total energy. The 13-year-olds and the 9-year-olds have the highest 95th percentile at 26 and 23E%, respectively. A higher proportion of the 4-, 9- and 13-year-olds had more than 10% of their energy from added sugar than the youngest children (1- and 2-year-olds) and adults.

Table 11. Percent of energy (E%) from added sugar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

	Mean	Median	95th percentile	Proportion (%) with E%>10%	Proportion (%) with E%>15%
1-year-old	9	9	18	39	14
2-year-old	10	10	19	47	16
4-year-old	13	13	21	76	32
9-year-old	14	14	23	80	44
13-year-old	15	15	26	84	51
Men	8	8	17	30	8
Women	9	8	19	32	10

8.2.3 Exposure to added sugar if 100% of the consumed soft drink, 'saft' and nectar contain intense sweeteners (100% scenario)

The estimated total intakes of added sugar in the 100% scenario are shown in Table 12. The mean intake increased with age among children and adolescents. The highest 95th percentiles were estimated for the 13-year-olds and the adult men with an intake at 107 and 92 g/day respectively. The lowest 95th percentile was found for the 2-year-olds.

Table 12. Total intake of added sugar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

	Mean (g/person/day)	Median (g/person/day)	95th percentile (g/person/day)
1-year-old	24	21	52
2-year-old	24	22	46
4-year-old	35	34	65
9-year-old	48	45	89
13-year-old	51	46	107
Men	39	31	92
Women	30	25	69

Table 13 shows E% deriving from added sugar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners for different age groups. Adults have a lower mean E% than all the children and adolescents. The 13-year-olds have the highest mean E% from added sugar. Energy from added sugar in this age group represents 11E% of the total energy intake. Men and women have the lowest mean E% from added sugar which represents 6E% of the total energy. The 13-year-olds and the 9-year-olds have the highest 95th percentile at 19 and 17E% respectively. Among the 4-, 9- and 13-year-olds about 50% received more than 10% of the energy from added sugar, while only 25% and 17% of the 1- and 2-year-olds, respectively, received more than 10% of the energy from added sugar.

Table 13. Percent of energy (E%) from added sugar if 100% of the consumed soft drinks, 'saft' and nectar contain intensive sweeteners

	Mean	Median	95th percentile	Proportion (%) with E%>10%	Proportion (%) with E%>15%
1-year-old	8	7	15	25	5
2-year-old	7	7	13	17	2
4-year-old	10	10	16	49	7
9-year-old	10	10	17	51	13
13-year-old	11	10	19	51	17
Men	6	5	12	11	2
Women	6	6	13	11	2

8.3 Risk characterisation of intake of added sugar

The Norwegian recommendations for nutrition and physical activity recommend that the percentages of energy from added sugar should not exceed 10E% (Directorate for Health and Social Affairs, 2005b).

In the current situation, the mean percentages of energy from added sugar are below the recommended intake of maximum 10E% only among 1-year-olds and adults. All other age groups of children have a mean intake higher than the recommendation. About 85% of the children (4-, 9- and 13-year-olds) had more than 10% of the energy from added sugar. The proportion with more than 10% of the energy from added sugar was somewhat lower among the youngest children

In the 50% scenario, the mean percentages of energy from added sugar are below 10E% among both the 1- and 2-year-olds and the adults. The mean E% from added sugar among the older children is higher. About 80% of the children (4-, 9- and 13-year-olds) had more than 10E% of the energy from added sugar. The proportion with more than 10E% of the energy from added sugar was somewhat lower among the youngest children.

In the 100% scenario, the mean percentages of energy from added sugar are below or close to 10E% among all age groups. About 50% of the children (4-, 9- and 13-year-olds) had more than 10% of the energy from added sugar.

In summary, the 100% scenario results in acceptable mean percentages of energy from added sugar compared to the recommendations. However, even with the 100% scenario a large proportion of the children, aged 4-13 years, have a higher percentage of the energy from added sugar compared to the recommendations. Moving from the current level to the 100% scenario has the largest impact on the E% for added sugar for the age groups 2, 4, 9 and 13 years because sugar

sweetened soft drinks and 'saft' contribute with large proportions of added sugar in these age groups (Table 7).

Figure 8-14 show curves for the distribution of E% at the current level and in the 50% and 100% scenarios among different age groups.

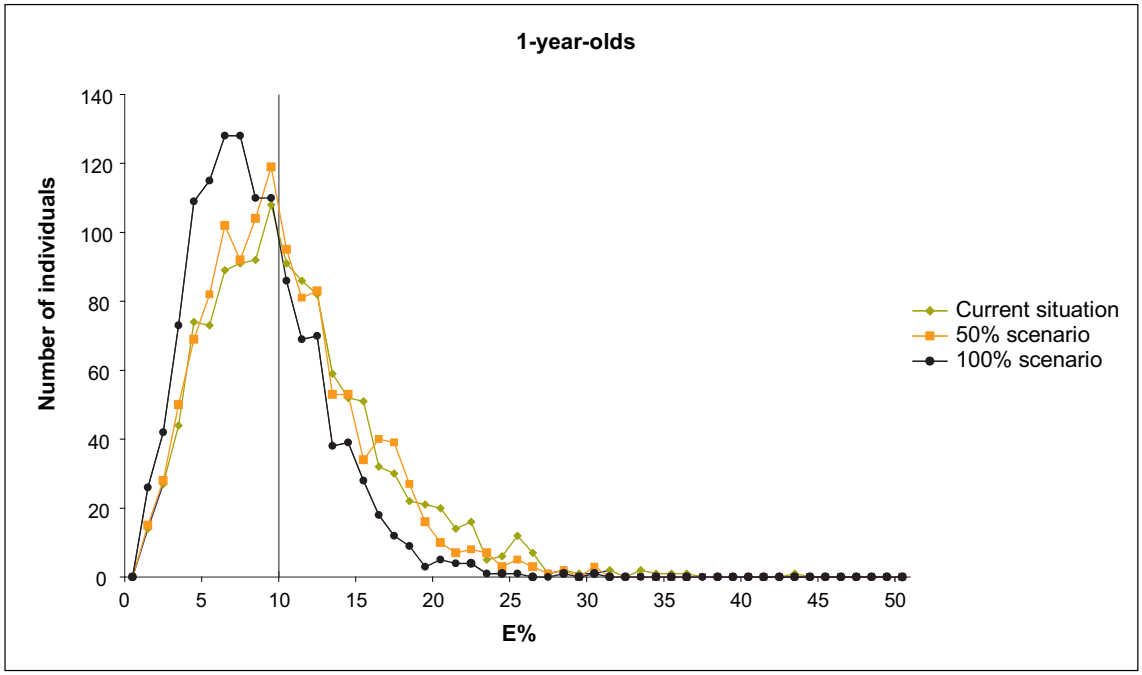


Figure 8. Distribution of E% at the current level and in the 50% and 100% scenarios in 1-year-olds

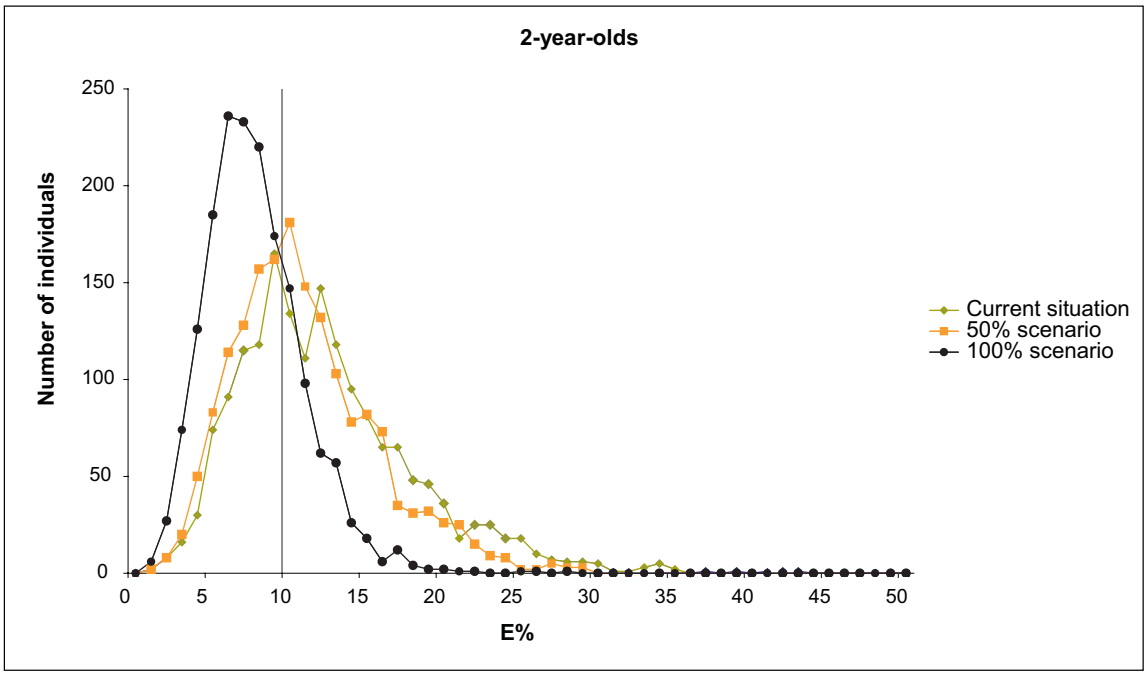


Figure 9. Distribution of E% at the current level and in the 50% and 100% scenarios in 2-year-olds

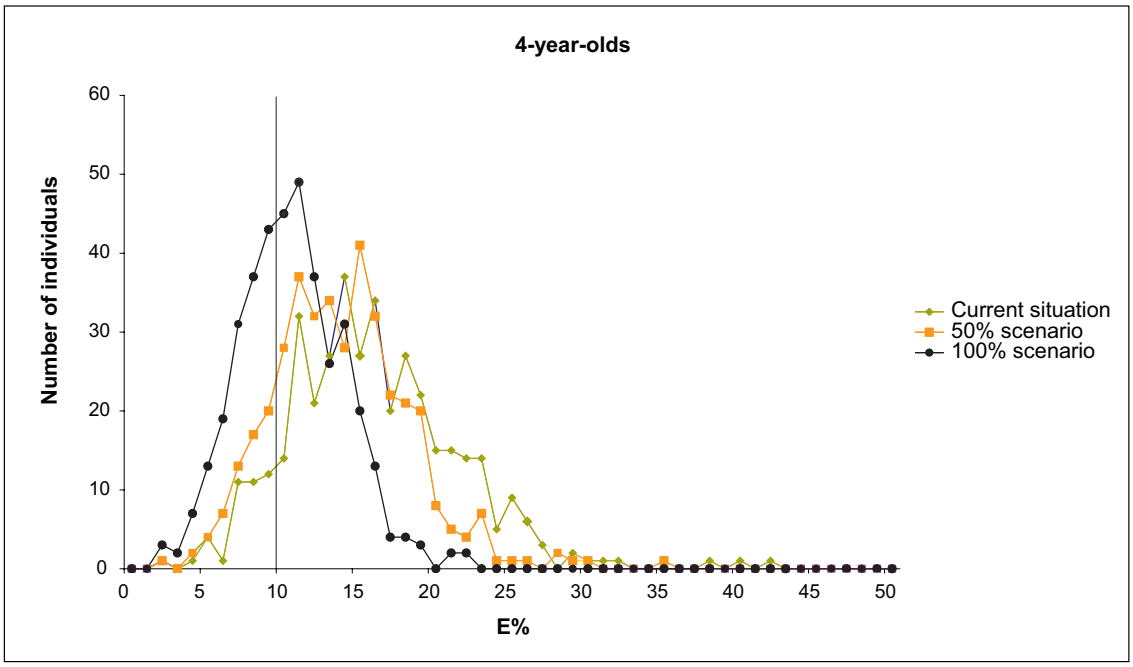


Figure 10. Distribution of E% at the current level and in the 50% and 100% scenarios in 4-year-olds

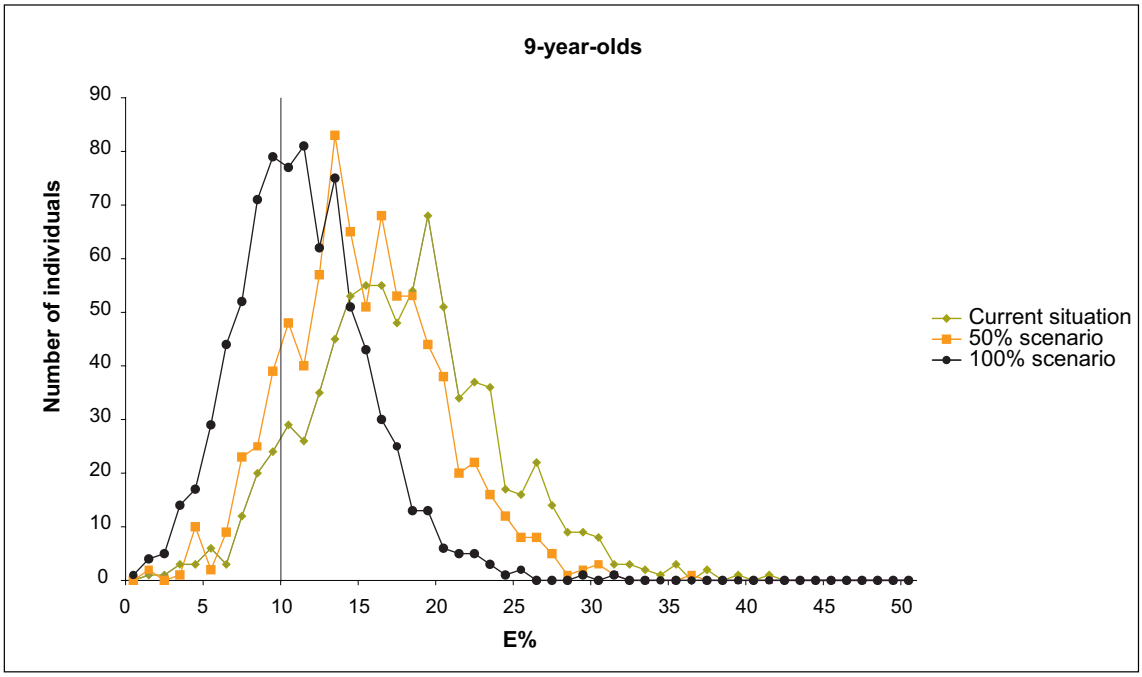


Figure 11. Distribution of E% at the current level and in the 50% and 100% scenarios in 9-year-olds

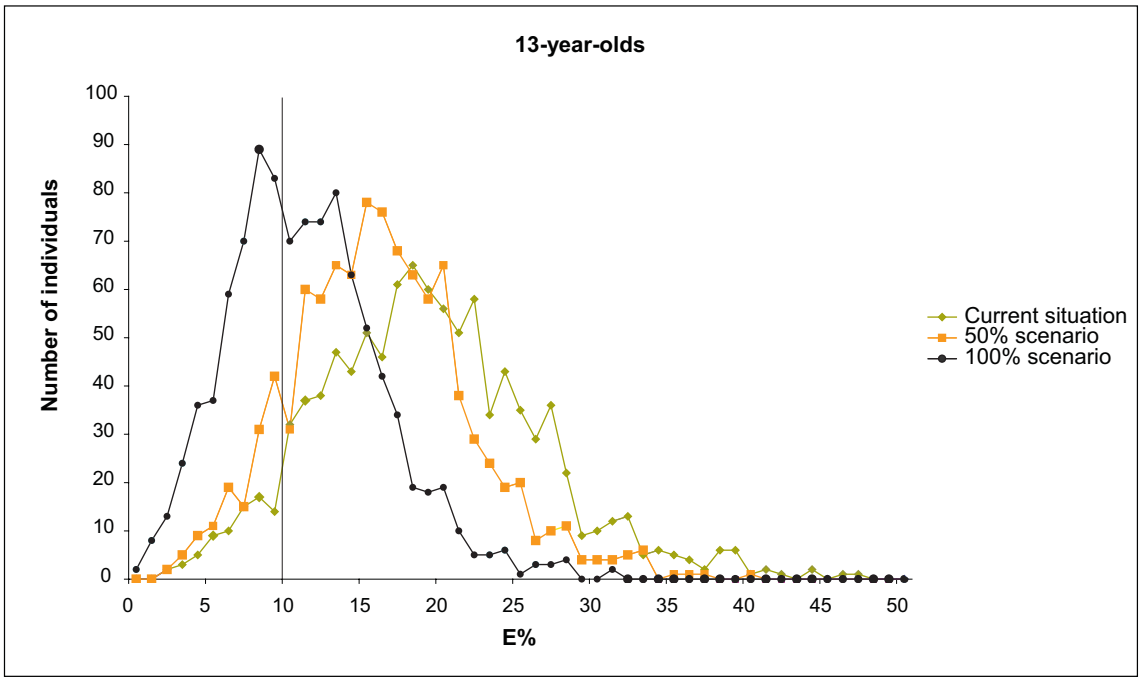


Figure 12. Distribution of E% at the current level and in the 50% and 100% scenarios in 13-year-olds

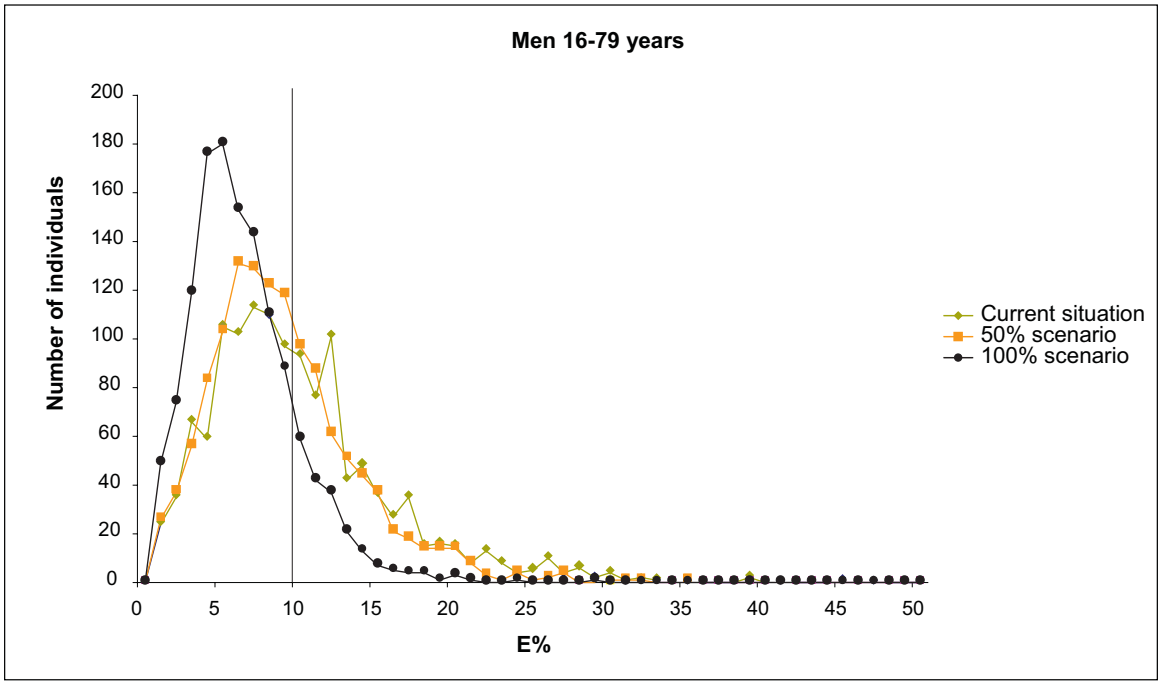


Figure 13. Distribution of E% at the current level and in the 50% and 100% scenarios in men

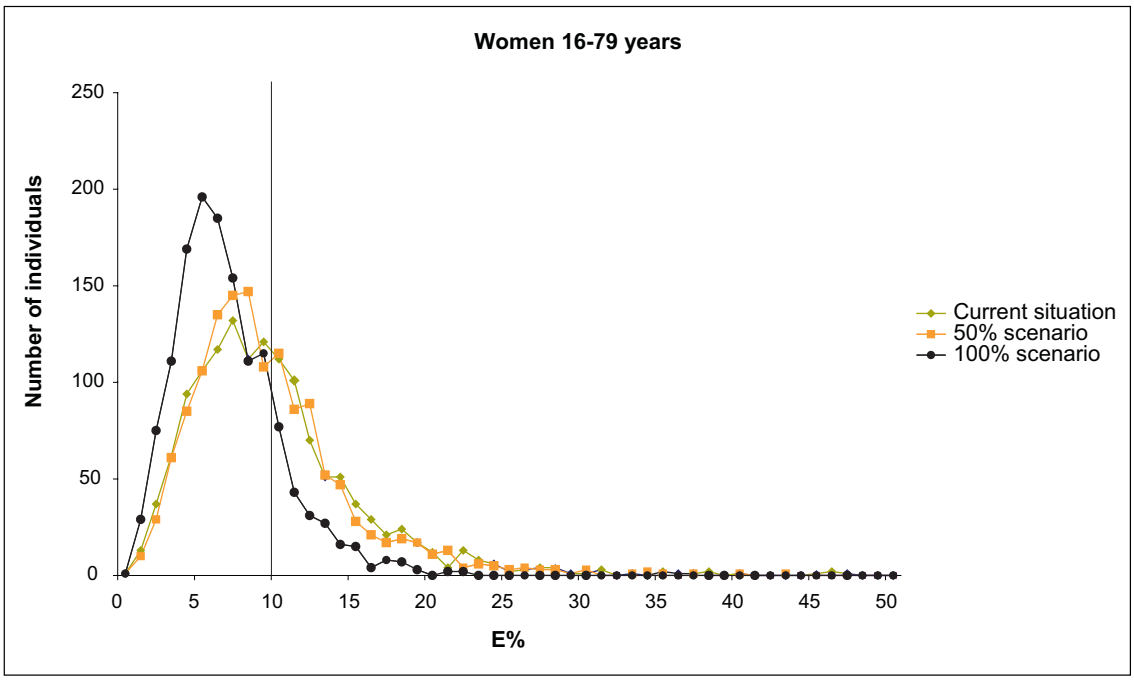


Figure 14. Distribution of E% at the current level and in the 50% and 100% scenarios in women

8.4 Conclusions risk assessment of intake of added sugar

In the current situation the mean percentage of energy deriving from added sugar is high among Norwegian children and adolescents. Sugar sweetened soft drinks, 'saft' and nectar are the most important sources of added sugar. Among the 4-, 9- and 13-year-olds about 85% had more energy from added sugar than the recommended maximum level of 10E%. Among the 1- and 2-year-olds the proportions were 43% and 56%, respectively.

In the scenario, where it is assumed that 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners and the other half contains added sugar, the estimated mean percentage of energy from added sugar is below or close to 10E% among both 1- and 2-year-olds and adults. However, 76-84% of the older children (4- to 13 years of age) still have a percentage of energy from added sugar higher than 10E%.

In the scenario where it is assumed that 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners, the mean percentage of energy from added sugar is estimated to be below or close to 10E% for all age groups. About 50% of the children aged 4- to 13 years still have an energy percentage from added sugar higher than 10E%, while these proportions among 1- and 2-year-olds are 25% and 17%, respectively.

9 Risk assessment of intense sweeteners and benzoic acid from soft drinks, 'saft' and nectar

The risk assessments of the intense sweeteners aspartame, acesulfame K, saccharin, cyclamate and the preservative benzoic acid are based on earlier opinions from SCF, EFSA, JECFA and other European Countries. New scientific toxicological literature published after the last published opinions from SCF/EFSA have been evaluated and taken into consideration.

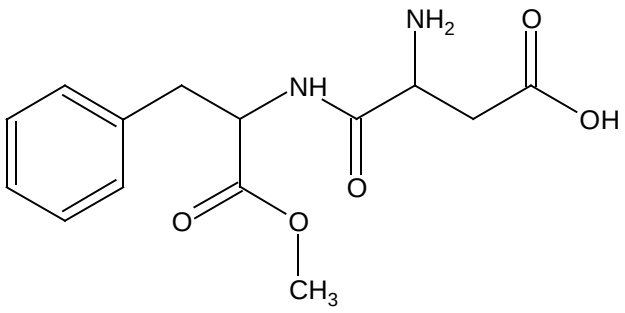
The intense sweetener sucralose was authorised for use in Norway in 2005. As the intake calculations in this evaluation are based on the actual content of intense sweeteners, and sales volumes for 2004, it has not been possible to perform intake estimates for sucralose. However, a risk assessment of sucralose based on intake estimates from some other countries has been carried out in this evaluation.

It was not reported any use of neohesperidin DC and thaumatin in soft drinks, 'saft' and nectar by the industry, and no risk assessment was performed for these intense sweeteners.

Table 14. An overview of the ADI for the intense sweeteners and benzoic acid and the year of allocation

Compound	ADI (mg/kg bw)	Year of allocation
Aspartame	0-40	1981 by JECFA, 1984 by SCF
Acesulfame K	0-9	1984 by SCF
	0-15	1991 by JECFA
Saccharin	0-5	1993 by JECFA, 1995 by SCF
Cyclamate	0-7	2000 by SCF
	0-11	1982 by JECFA
Sucralose	0-15	1991 by JECFA, 2000 by SCF
Benzoic acid	0-5	1974 by JECFA, 2002 by SCF

9.1 Aspartame (E951)



Aspartame

Aspartame was authorised for use in USA in 1974, but was withdrawn from the market a few months later, because of possible induction on brain cancer in rats. Following a reassessment of new studies in rats, a reauthorisation was given in USA in 1981 for use in solid food. This authorisation was extended to soft drinks in 1983 and for its use as a general sweetener in 1986.

In 1994 aspartame was authorised for use in EU by the European Parliament, and its use is today permitted in more than 90 countries (AFSSA, 2002).

9.1.1 Hazard characterisation of aspartame

9.1.1.1 Evaluations by SCF/EFSA

Aspartame has been evaluated by SCF in 1984, 1988, 1996, 2002 and as recently as in 2006 by EFSA. In 1984, an ADI of 0-40 mg/kg bw was allocated based on a no observed adverse effect level (NOAEL) established from long-term studies (SCF, 1985). In 1988, on new data concerning the effect of aspartame on blood and tissue levels of phenylalanine and the possibility of behavioural and other neurotoxic effects was evaluated. SCF concluded that when aspartame is consumed at levels within the ADI-limit there is no significant risk for an aspartame induced neurotoxic effect in the brain (SCF, 1989). At the 107th meeting of SCF in June 1997, SCF responded to a reported connection between aspartame and increases in the incidence of brain tumours in USA reported by Olney *et al*. in 1996 (*http://europa.eu.int/comm/food/fs/sc/old-comm7/out13_en.html*). The SCF concluded that the data did not support the proposed biphasic increase in the incidence of brain tumours in USA during the 1980s. In 2002, SCF published an updated opinion on the safety of aspartame where they evaluated the intake of aspartame in relation to brain tumours and seizures, headaches, allergies, and changes in behaviour and cognitive function (SCF, 2002a). Based on all available data in animals and humans, SCF concluded that there is no evidence to suggest that there is a need to revise the outcome of the earlier risk assessment or the ADI previously established for aspartame. In May 2006, EFSA re-evaluated aspartame on the basis of a new carcinogenicity study performed at the European Ramazzini Foundation of Oncology and Environmental Science (ERF) by Soffritti *et al*. (2006).

Aspartame was administered in feed to 8 weeks old Sprague-Dawley rats (100-150/sex/group) at concentrations 0, 80, 400, 2000, 10000, 50000 and 100000 ppm, equivalent to 0, 4, 20, 100, 500, 2500 and 5000 mg/kg bw/day. The treatment lasted until natural death of the animals. The feed consumption was monitored every second week until week 104 and the weight (every second week until week 110, followed by every eight weeks) of individual animals was measured until week 152. The last animal died 159 weeks old. Histopathology on all organs was routinely performed. Malignant schwannomas and olfactory neuroblastomas were characterised by immunhistochemical staining. The authors reported a significant positive trend in the number of animals bearing malignant tumours in both sexes. A significant positive trend of lymphomas/leukaemias was reported in both sexes as well as a significant increased incidence at 400 – 100000 ppm compared to control in female rats. In addition a significant positive trend in preneoplastic and neoplastic lesions in the renal pelvis and ureter of females was reported. The incidence of malignant schwannomas of the peripheral nerves was reported with a positive trend in males. Finally, a significant positive trend in hyperplasia of the olfactory epithelium in both sexes, with statistically significant difference at 10000 – 100000 ppm compared to control was reported for both sexes. The authors concluded that aspartame is a multipotential carcinogenic compound (Soffritti *et al*., 2006).

The EFSA Panel on food additives, flavourings, processing aids and materials in contact with food (AFC), however, concluded that the increased incidence of lymphomas/leukaemias reported in the study was unrelated to the treatment with aspartame, given the high background incidence of chronic inflammation and the lack of positive dose-response relationship. Concerning the malignant schwannomas, the EFSA Panel noted that the numbers of tumours were low, the dose-response relationship was very flat over a wide dose range and there was also uncertainty about the diagnosis of these tumours. The preneoplastic and neoplastic lesions of the renal pelvis, ureter and bladder along with renal calcification were probably treatment-related according to the EFSA Panel. However, such effects are specific to rats and caused by high dosages of irritant chemicals and have no relevance for humans. In the opinion of the EFSA Panel, the aggregation of all malignant tumour incidences or all malignant tumour-bearing animals for statistical purposes is not scientifically justified. The EFSA Panel concluded on the basis of

all evidence currently available from the ERF study, other studies and previous evaluations, that there is no reason to revise the previously established ADI for aspartame of 0-40 mg/kg bw (EFSA, 2006).

VKM notes that the incidence of lymphomas/leukemias is not very high and both the incidence of the control group and the group with highest aspartame doses are within the range of historical controls. To include both hyperplasic and dysplastic lesions, and carcinomas in the aggregation of all malignant tumours is not supported by VKM.

9.1.1.2 Evaluations by other international or national bodies

Aspartame was evaluated by JECFA in 1980 and 1981, and an ADI of 0-40 mg/kg bw based on a no observed effect level (NOEL) of 4 g/kg bw in a long-term study in rats (JECFA, 1980a, 1981a).

In 2002, the French Food Safety Agency (AFSSA) assessed a possible link between the exposure to aspartame and the incidence of brain tumours in humans (AFSSA, 2002). No such relationship was observed at the current state of scientific knowledge. The evaluation of aspartame by AFSSA is included in the opinion by SCF in 2002 (SCF, 2002a).

9.1.1.3 Recent studies not included in previous evaluations

New human studies

The US National Cancer Institute (NCI) recently published an abstract describing a study where they had examined aspartame-containing beverage consumption in relation to incidence of haematopoietic and brain cancers among 340045 men and 226945 women aged 50-69 years in the NIH-AARP Diet and Health Study. They concluded that the consumption of aspartame-containing beverages did not raise the risk of haematopoietic or brain malignancies (NCI, 2006).

New animal studies

Carcinogenicity

The US National Toxicology Program (NTP) has carried out three 9-month carcinogenicity studies with aspartame in the genetically modified mouse models Tg.AC hemizygous mice, p53 haploinsufficient mice and Cdkn2a deficient mice. These models with genetic modifications are more sensitive to carcinogens. The study protocol was the same for all the three mouse models, and the studies were performed according to Good Laboratory Practice (GLP). Groups of 15 male and 15 female mice were fed diets containing 0, 3125, 6250, 12500, 25000 or 50000 ppm aspartame, equivalent to 490, 980, 1960, 3960 and 7660 mg/kg bw for males and 550, 1100, 2260, 4420 and 8180 mg/kg bw for females, for 40 weeks starting at 7-9 weeks of age. Complete histopathology was performed on all control animals and mice given 50000 ppm, while limited histopathology was performed on the remaining dosages. In the Tg.AC hemizygous mice there were some neoplasms and non-neoplastic lesions that occurred with slightly different incidences in exposed and control groups. The lesions had no relation to aspartame dose and some lesions occurred at the same incidence in historical controls. For all three mouse models there were therefore no evidence of enhanced tumour formation in mice exposed to aspartame (NTP, 2005a).

Genotoxicity

The bone marrow micronucleus test was performed on male F344/N rats given aspartame (0, 500, 1000 and 2000 mg/kg) dissolved in corn oil by gavages three times at 24 hour intervals. Vehicle control animals were given corn oil only. The positive control animals received cyclophosphamide (25 mg/kg). Twenty-four hours after last treatment the animals were sacrificed. The frequency of micronucleated cells were scored in 2000 polychromatic erythrocytes (PCEs)

in each of five animals per dose group. In addition, the percentage of PCEs among 200 erythrocytes in the bone marrow of each animal was scored as a measure of toxicity. The percentage of PCEs was not altered. No increase in micronucleated polychromatic erythrocytes was observed in bone marrow of rats given aspartame (NTP, 2005a).

The US NTP (NTP, 2005a) performed a peripheral blood micronucleus test at the end of three 9-month carcinogenicity studies with aspartame in the genetically modified mouse models Tg.AC hemizygous mice, p53 haploinsufficient mice and Cdkn2a deficient mice (se experimental details above). At the end of the study, peripheral blood samples were obtained from male and female mice. The frequency of micronuclei were measured in 2000 normochromatic erythrocytes in up to 12 Tg.AC hemizygous, 15 p53 haploinsufficient and 15 Cdkn2a deficient mice per exposure group. The percentage of PCEs among 1000 erythrocytes in peripheral blood was scored as a measure of toxicity. Negative results were obtained in male and female Tg.AC hemizygous and Cdkn2a deficient mice, and in male p53 haploinsufficient mice, while significant positive results in female p53 haploinsufficient mice receiving 50000 ppm were reported. The response was small and not considered to be of biological significance. A small increase in magnitude and response in only one sex is generally considered by NTP to be of uncertain biological significance. No alteration in PCEs was observed (NTP, 2005a).

Memory loss
Male Sprague-Dawley rats (225g) were in a T-maze performance test shown to have reduced memory after exposure to aspartame (250 mg/kg bw) in the drinking water for 4 months. The control group was given ordinary tap water. The number of animals in each group is not given. The rats were trained for 2 weeks with chocolate as reward before the start of the experiment. In addition to memory loss, an increase in muscarinic receptor densities was found in the brain (Christian *et al*., 2004). The experimental details in the study are incompletely reported and the memory test was not performed according to OECD guidelines. VKM questions whether it is appropriate to use chocolate as a reward when testing aspartame.

New *in vitro* studies

Genotoxicity
Chromosomal aberrations (CA), sister chromatid exchanges (SCE) and micronuclei (MN) were measured in human lymphocytes after exposure for 500, 1000 and 2000 µg/ml aspartame for 24 and 48 hours. Mitomycin-C (0.3 µg/ml) was used as positive control. Control cells without treatment were only reported for 24 hours. A weak response was reported on CA at all three dosages and on MN at the highest dosage. However, the response was not dose-dependent. No effect was found on SCE. The effect of aspartame on CA, SCE and MN does not indicate a genotoxic potential. Aspartame was also tested for mutagenicity in *Salmonella typhimurium* TA98 and TA100 strains at concentrations of 50, 100, 250, 500, 1000 and 2000 µg/plate with and without metabolic activation. As positive controls 2-aminofluorene (20 µg/plate) and 4-nitrophenylene (200 µg/plate) were used with and without metabolic activation, respectively. Aspartame was found not to be mutagenic in *Salmonella* mutagenicity test (Rencuzogullari *et al*., 2004).

A bacterial mutagenicity test was performed in *Salmonella typimurium* strains TA97, TA98, TA100, TA1535 and TA1537 with aspartame either in buffer or in the presence of a S9 mix for 20 minutes at 37 °C. Histidine-independent mutant colonies arising on these plates were counted following incubation for 2 days at 37 °C. Each trial consisted of triplicate plates of concurrent positive and negative controls and five doses of aspartame (0, 100, 333, 1000, 3333 and 10000 µg/plate). No increased mutagenicity was detected (NTP, 2005a).

Neurotoxicity
Differentiating mouse NB2a neuroblastoma cells were exposed to quinoline yellow and aspartame or a mixture of these, and the neurotoxic potential was measured as an inhibition of

neurite outgrowth. A concentration curve on neurite inhibition was made for each compound and different combinations of the compounds were tested. Quinoline yellow and aspartame were found to have synergistic effects on inhibition of neurite outgrowth using two different models for evaluating the interactions. Cytotoxicity was measured by trypan blue exclusion (Lau *et al*., 2006).

VKM concludes that the study seems well conducted, but the relevance for risk assessment is limited since aspartame as such will be metabolised to aspartic acid, phenylalanine and methanol in the intestine and not reach the nerve cells in humans.

9.1.1.4 Conclusion hazard characterisation of aspartame

VKM fully agrees with the conclusion in the last opinion from EFSA which evaluated the carcinogenicity study performed by the ERF (EFSA, 2006). Based on new toxicological data on aspartame, it is concluded that it is not necessary to revise the existing ADI of aspartame of 0-40 mg/kg/bw.

9.1.2 Exposure assessment of aspartame

The calculated exposure to aspartame from soft drinks, 'saft' and nectar has been based on actual content level used in soft drink, 'saft' and nectar and the sales volumes reported by the industry (weighted average content). Consumption data were taken from Norwegian dietary surveys among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

In the intake estimates where it is assumed that 50% and 100% of all consumed soft drinks, 'saft' and nectar contain intense sweeteners, the weighted average value for the content of aspartame is used.

Intake of aspartame from other sources than soft drinks, 'saft' and nectar are only available for adults. The total intake of aspartame has therefore not been calculated for children and adolescents. Each table and figure shows the estimated mean daily intake, median daily intake and the daily intake at the 95th percentile.

9.1.2.1 Exposure to aspartame from soft drinks, 'saft' and nectar at the current level

The estimated exposure to aspartame from soft drinks, 'saft' and nectar at the current intake level is shown in Table 15 and Figure 15. One- and two-year-old children were found to have the highest intake of aspartame, in which the 95th percentile was estimated to 8.2 and 8.4 mg/kg bw/day, respectively. The lowest 95th percentile of 3.2 mg/kg bw/day was estimated for 4-year-old children.

Table 15. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar at the current level

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	188	2.3	1.0	8.2
2-year-old	380	2.2	1.2	8.4
4-year-old	61	1.5	1.0	3.2
9-year-old	183	1.4	1.0	3.8
13-year-old	229	1.3	0.8	4.2
Men	423	1.0	0.4	4.4
Women	582	1.3	0.5	5.4

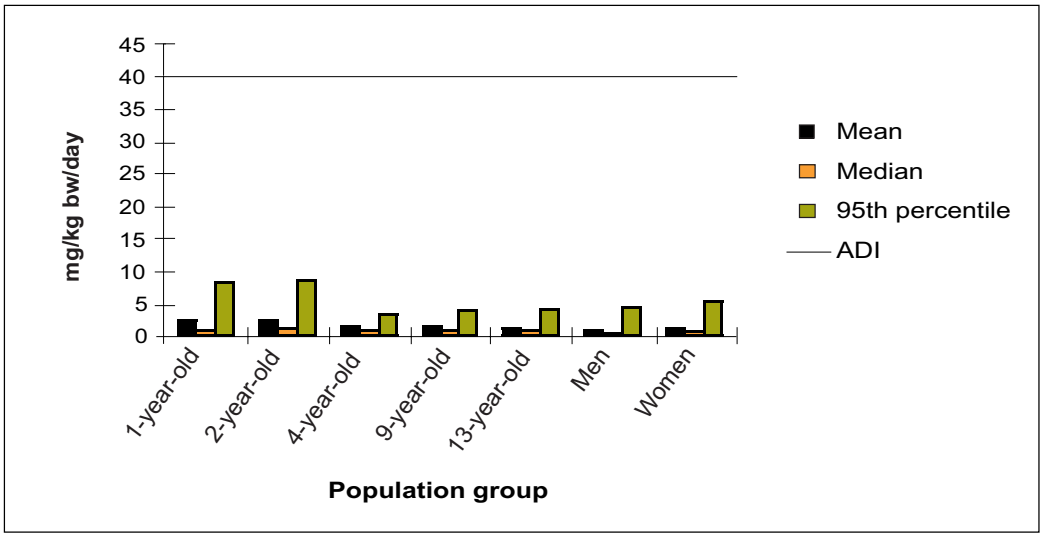


Figure 15. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar at the current level

9.1.2.2 Current exposure to aspartame from other sources

The aspartame intake from other sources, such as yoghurt, sweets, lozenges, chewing gum and table top sweeteners is based on analytical values of aspartame from the different food categories, and it is calculated for a person weighing 60 kg (Table 16). The current intake of aspartame from other sources among children and adolescents was not available. An overview of the authorised concentrations of aspartame in different categories of foods is given in Annex 4.

Table 16. The current aspartame intake from other sources among adults (mg/kg bw/day)

	Mean	Median	95th percentile
Adults	0.3	0.2	0.8

9.1.2.3 Exposure to aspartame if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (50% scenario)

The aspartame intake was estimated with the assumption that half of the consumed soft drinks, 'saft' and nectar contain aspartame at the average level reported by industry (weighted average content). The estimated aspartame intake in the 50% scenario was highest for the 1- and 2-year-old children, with an intake within the 95th percentile of 4.1 and 5.1 mg/kg bw/day, respectively (Table 17 and Figure 16).

Table 17. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	883	1.3	0.8	4.1
2-year-old	1487	1.8	1.3	5.1
4-year-old	283	1.6	1.4	3.6
9-year-old	669	1.8	1.5	4.0
13-year-old	841	1.8	1.5	4.2
Men	1081	1.0	0.5	3.5
Women	1155	0.8	0.4	3.0

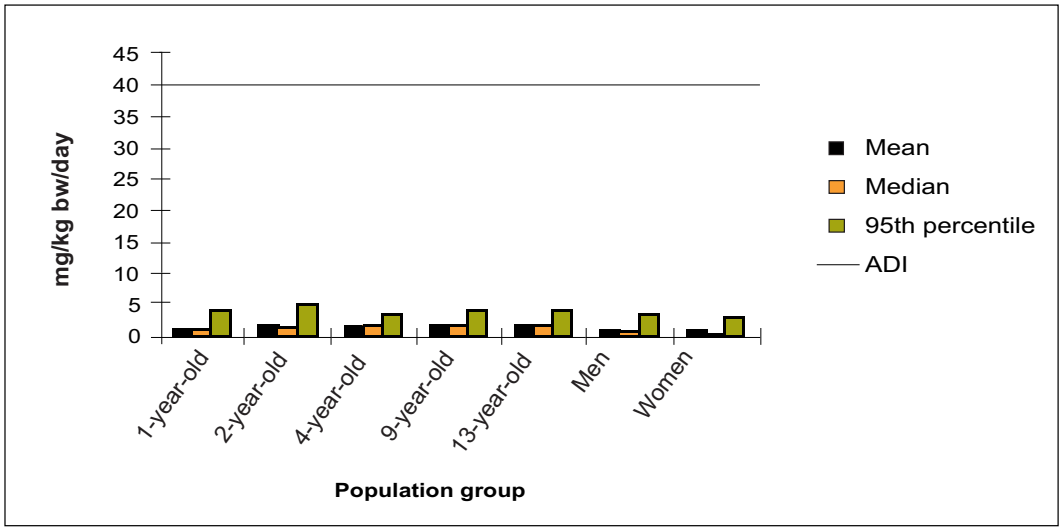


Figure 16. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.1.2.4 Exposure to aspartame if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (100% scenario)

The aspartame intake was estimated with the assumption that all consumed soft drinks, 'saft' and nectar contain aspartame at the average level reported by the industry. The aspartame intake was highest for the 2-year-olds and 13-year-olds, with an intake within the 95th percentile of 10.2 and 8.4 mg/kg bw/day, respectively (Table 18 and Figure 17).

Table 18. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	883	2.5	1.6	8.2
2-year-old	1487	3.5	2.5	10.2
4-year-old	283	3.2	2.9	7.1
9-year-old	669	3.6	3.1	8.0
13-year-old	841	3.6	3.0	8.4
Men	1081	1.9	1.0	6.9
Women	1155	1.7	0.9	6.1

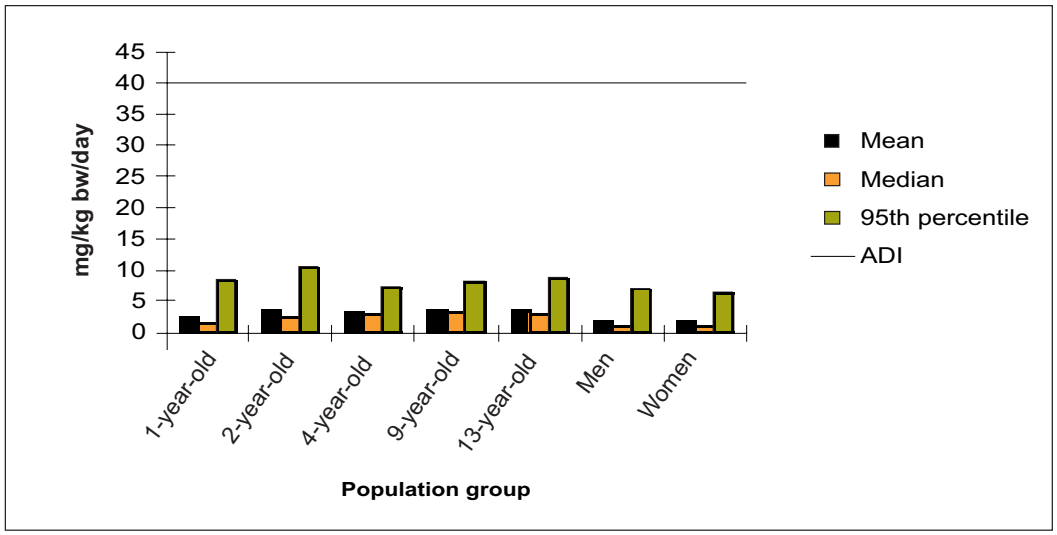


Figure 17. Intake of aspartame among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.1.2.5 *Previous reports of intake of aspartame in European countries*

A consumer survey was carried out among Italian female teenagers who regularly consume soft drinks and table top sweeteners. A total of 362 subjects participated in a detailed food survey by recording, at brand-name level, all food and beverages ingested over 12 days, divided in three 4-days diaries collected in different months. For each sugar-free product, producers provided the concentration of intense sweeteners. A worst-case scenario for the intake was performed where it was assumed that all food products could be substituted with the corresponding sugar-free version. Within each food category, the highest concentration levels of intense sweeteners were selected. The intake of aspartame in a worst-case scenario calculated at the 95th percentile was reported to be 7.4 mg/kg/bw for female teenagers with a high consumption of sugar-free soft drinks (Arcella *et al*., 2004). This study provides a comprehensive assessment of intake at brand-name level and with intake reported at different times of the year. The intake data collection and product concentration data are from the same period of time. The study did not include other groups with high predicted intake, like children and diabetics.

A survey of intense sweeteners, including aspartame, was performed among the Dutch population. A total of 6250 subjects at the age 1 to 97 years participated in the study and had to fill out 2-days food intake diaries from 1997 to 1998. Actual concentration of the sweeteners in the products (purchased in 2003), divided over several food categories, were analysed and used for the intake estimates. The intake of sweeteners was calculated both for the whole population and for consumers only. A worst-case scenario for the intake among consumers was performed. It was assumed that all foods in the various food categories contained aspartame at the average of the analysed concentrations, corrected for market share. The particular food was consumed at the 95th percentile intake estimate for the consumer population. The intake of aspartame in this worst-case scenario was highest for 1- to 4-year-old children (consumers only) with a reported intake of 8 and 3 mg/kg bw/day from soft drinks and squashes respectively (van Rooij-van den Bos *et al*., 2004). A weakness of the study is that the intake and concentration data do not relate to the same time period or to the same product. The intake estimates are based on food categories where all products in a food category are assumed to contain the same level of intense sweeteners.

The intake of intense sweeteners from soft drinks among British children (n = 1110), 1.5- to 4.5-year-old, was estimated in a 7-days dietary survey published by the Food Standard Agency (FSA) in 2003. The intake estimates were based on consumers only and the actual levels of sweeteners as reported by manufacturers. For the high consumers (97.5th percentile) the aspartame intake was estimated to 12.0 mg/kg bw/day (FSA, 2003). It is not clear if the data for high consumers are related to recorded body weight or to assumptions, or whether brand information is used in the intake calculations. The total intake of intense sweeteners is not given.

The estimated intake of sweeteners, including aspartame, in persons with diabetes was performed in a Swedish study. Participants (n = 1120), adults and children, were asked to complete a questionnaire about their intake of sweeteners. The major source of sweeteners was beverages. The maximum amounts of each sweetener authorised in food categories was used in the calculations. In a worst-case calculation based on the 10 or 20 children with highest intake of beverages, an aspartame intake of 44 and 32 mg/kg bw/day was reported, respectively. However, it is assumed that this is an overestimated intake for aspartame since the industry probably uses lower levels of aspartame in their beverages (Ilbäck *et al*., 2003). The inclusion of conservative assumptions at each point in the intake calculation resulted in an unrealistic high estimated intake.

A pilot survey of the intake of intense sweeteners in 1- to 19-year-old children with diabetes (n = 191) was performed by the Norwegian Food Control Authority in 2000. The control group consisted of pupils (n = 52) aged 9-13 years from primary school. The participants were asked to complete a food frequency questionnaire (FFQ) about their intake of intense sweeteners. The content of sweeteners was taken from the label of the product, given by the manufacturers or provided by analyses of the food item. The average amount of sweeteners was used in the

calculations. The intake of aspartame within the 90th percentile was estimated to 7.7 and 2.5 mg/kg bw/day for the diabetic and control group, respectively (Drøpping, 2003). A weakness of the study is that the control group and treatment group contain children at different ages. The intake estimates are based on a FFQ which do not include brand information.

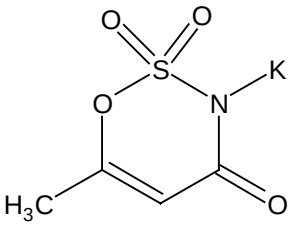
A similar study in young insulin-dependent diabetics (n = 227) was performed in France. All sugar-free products were assumed to be sweetened with the same intense sweetener at the maximum authorised concentrations. The intake of beverages made the greatest contribution to the intake. At the 97.5th percentile, an aspartame intake of 7.8 mg/kg bw/day was reported for consumers only (Garnier-Sagne *et al*., 2001). The assumption about the distribution of sweeteners in food products and the use of maximum authorised concentrations in the intake estimates are too conservative to allow the data to be considered as realistic estimates, although they do provide an upper bound of a possible intake.

9.1.3 Risk characterisation of aspartame intake

For aspartame an ADI of 0-40 mg/kg/bw was allocated by SCF in 1985 and sustained in the EFSA opinion from 2006.

In the 100% scenario, where all consumed soft drinks, 'saft' and nectar are assumed to contain aspartame at the average level reported by the industry, the group with the highest estimated intake of aspartame, 2-year-old children, will have an intake within the 95th percentile of 25.5% of the ADI for aspartame. The intake from other sources is not included in this calculation. However, it is not likely to contribute with a considerable amount to the estimated intake since most of the aspartame intake is from beverages. This is in line with reports on aspartame intake from other European countries.

9.2 Acesulfame K (E950)



Acesulfame K

Acesulfame K has been authorised for use in foods in Europe since 1983, in USA since 1988 and in Canada since 1994.

9.2.1 Hazard characterisation of acesulfame K

9.2.1.1 Evaluations by SCF/EFSA

Acesulfame K has been evaluated by SCF in 1984, 1991 and in 2000. In 1984, an ADI for acesulfame K of 0-9 mg/kg bw/day was allocated based on the NOAEL of 900 mg/kg bw/day from a 2-year study in dogs as the most sensitive species, compared to rats with a reported NOAEL of 1500 mg/kg bw/day (SCF, 1985). Acesulfame K was re-evaluated by SCF in 2000 considering new information on mutagenicity and comments from the Centre for Science in the Public Interest (CSPI) in USA who expressed concerns about the potential for carcinogenicity of acesulfame K. SCF considered that although the carcinogenicity studies are old they could still be used in the safety assessment of acesulfame K. Moreover, SCF did not agree with the interpretation of the CSPI that there is an indication of possible carcinogenicity from these studies. The one aberrant, positive mutagenicity finding in mouse bone marrow cells could not be replicated and all other mutagenicity findings were negative. Because of the greater kinetic

similarities between dog and human than between rat and human, SCF considered that the dog should remain the appropriate species to base ADI on, and reaffirmed its previous ADI of 0-9 mg/kg bw/day (SCF, 2000a).

9.2.1.2 *Evaluations by other international or national bodies*

Acesulfame K was evaluated by JECFA in 1981, 1983 and in 1990. No ADI was allocated in 1981 because of some shortcomings in the long-term/carcinogenicity studies in mouse and rat (JECFA, 1981b). JECFA evaluated acesulfame K again in 1983 where a detailed histopathology examination of the rat study was included. An ADI of 0-9 mg/kg bw/day was allocated for acesulfame K based on the 2-year study on dogs with a NOEL from the highest dosage tested of 900 mg/kg bw/day (JECFA, 1983). In 1991 JECFA reviewed new and previously published data on acesulfame K and considered whether the ADI might be increased based on a long-term rat study. Since the 2-year study in rats represented a greater proportion of the lifespan of the species than the 2-year study in dogs, including exposure *in utero*, JECFA decided that the ADI should be based on the NOEL in rats, i.e. 1500 mg/kg bw/day. The previously established ADI was changed to 0-15 mg/kg bw/day (JECFA, 1991a).

9.2.1.3 *Recent studies not included in previous evaluations*

New animal studies

Carcinogenicity

The US National Toxicology Program (NTP) has carried out three 9-month carcinogenicity studies with acesulfame K in the genetically modified mouse models Tg.AC hemizygous mice and p53 haploinsufficient mice, which are more sensitive to carcinogens. The study protocol was the same for both mouse models, and performed according to Good Laboratory Practice (GLP). Groups of 15 males and 15 female mice were fed diets containing 0, 3000, 10000, or 30000 mg/kg for 40 weeks starting at 7-9 weeks of age. Complete histopathology was performed on all control animals and mice given 30000 mg/kg bw, while all organs and tissues in all animals were examined for grossly visible lesions. In the Tg.AC hemizygous male mice there were a slight increase in the incidence of squamous cell skin papillomas in the 10000 mg/kg bw dose when papillomas at all sites were combined. The incidence of odontogenic tumours was slightly increased in Tg.AC hemizygous females that received 10000 mg/kg bw. Because spontaneous skin papillomas are relatively common in aging Tg.AC mice and since no dose-related increase in the incidence of formation of the different neoplasms were observed it was not considered to relate to acesulfame K administration. There were no increases in the incidences of neoplasms in p53 haploinsufficient mice. For both mice models there were therefore no evidence of enhanced tumour formation in mice exposed to acesulfame K (NTP, 2005b).

Mutagenicity

The US NTP performed a peripheral blood micronucleus test at the end of two 9-month carcinogenicity studies with acesulfame K in the genetically modified mouse models Tg.AC hemizygous mice and p53 haploinsufficient mice (se experimental details above). At the end of the study, peripheral blood samples were obtained from male and female mice. The frequency of micronuclei in 2000 normochromatic erythrocytes (NCEs) in up to 12 Tg.AC hemizygous and 15 p53 haploinsufficient mice per exposure group was examined. The percentage of PCEs among 1000 erythrocytes in peripheral blood was scored as a measure of toxicity. Negative results were obtained in male and female Tg.AC hemizygous mice, and in female p53 haploinsufficient mice, while the results in male p53 haploinsufficient mice receiving 10000 and 30000 mg/kg were judged to be positive although the responses were small. A small increase in magnitude and response in only one sex is considered by the NTP to be of uncertain biological significance. No alteration in PCEs was observed (NTP, 2005b).

New *in vitro* studies

Mutagenicity
Isolated hepatocytes from male F344 and Sprague-Dawley rats were exposed to acesulfame K (0, 50, 100, and 200 mM) for 20 hours. DNA damage was measured by the primary rat hepatocyte/DR assay which measures autioradiographically incorporation of ^{3}H-thymidine into nuclei of non-replicating cultured hepatocytes. The test is considered valid when the solvent and negative control yield negative values for the net nuclear grain count (NNG) and the positive control yields positive NNG values. As positive control 10 μM 2-aminofluorene was used. Acesulfame K was found to be negative in the DR assay (Jeffrey and Williams, 2000).

9.2.1.4 *Conclusion hazard characterisation of acesulfame K*
Choosing a conservative approach, VKM has applied the ADI on 0-9 mg/kg bw established by SCF in 2000 in its further risk assessment. It is concluded that on the basis of the new toxicological data on acesulfame K it is not necessary to revise the existing ADI on 0-9 mg/kg bw.

9.2.2 Exposure assessment of acesulfame K
The calculated exposure to acesulfame K from soft drinks, 'saft' and nectar has been based on actual content level used in soft drink, 'saft' and nectar and the sales volumes reported by the industry (weighted average content). Consumption data were taken from Norwegian dietary surveys among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

In the intake estimates where it is assumed that 50% and 100% of all consumed soft drinks, 'saft' and nectar contain intense sweeteners, the weighted average value for the content of acesulfame K is used.

Intake data of acesulfame K from other sources than soft drinks, 'saft' and nectar are only available for adults. The total intake of acesulfame K has therefore not been calculated for children and adolescents. Each table and figure shows the estimated mean daily intake, median daily intake and the daily intake at the 95th percentile.

9.2.2.1 *Exposure to acesulfame K from soft drinks, 'saft' and nectar at the current level*
The estimated exposure to acesulfame K from soft drinks, 'saft' and nectar at current levels of intake is shown in Table 19 and Figure 18. One- and two-year-old children were found to have the highest intake of acesulfame K, in which the 95th percentile was estimated to 6.5 and 5.4 mg/kg bw/day, respectively. The lowest 95th percentile of 1.1 mg/kg bw/day was estimated for men.

Table 19. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar at the current level

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	188	1.7	0.7	6.5
2-year-old	380	1.3	0.5	5.4
4-year-old	61	0.8	0.5	1.9
9-year-old	183	0.6	0.4	1.8
13-year-old	229	0.4	0.3	1.3
Men	408	0.3	0.2	1.1
Women	566	0.4	0.2	1.6

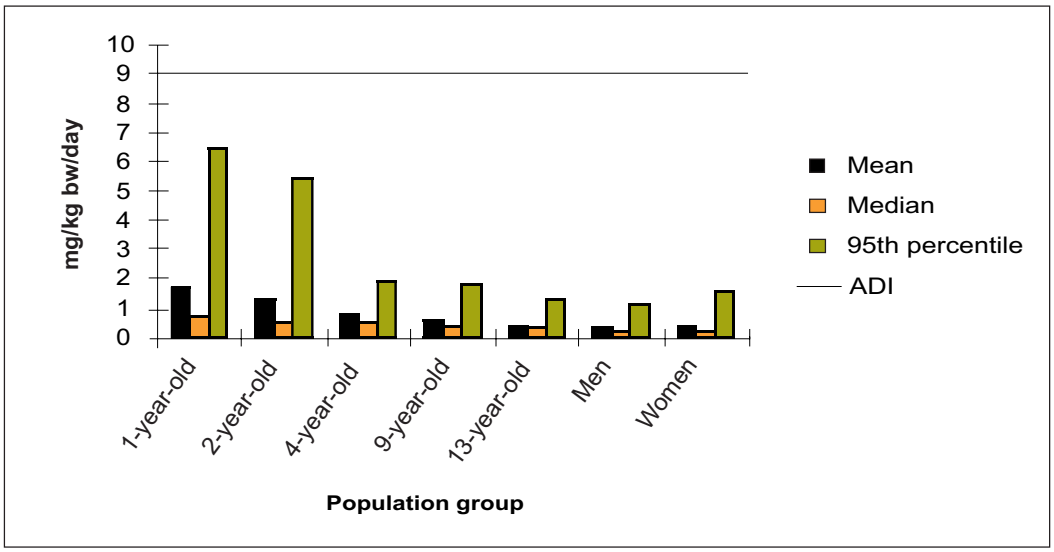


Figure 18. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar at the current level

9.2.2.2 *Current exposure of acesulfame K from other sources*

The acesulfame K intake from other sources, such as yoghurt, sweets, lozenges, chewing gum and table top sweeteners is based on analytical values of acesulfame K from the different food categories, and it is calculated for a person weighing 60 kg (Table 20). The current intake of acesulfame K from other sources among children and adolescents was not available. An overview of the authorised concentrations of acesulfame K in different categories of foods is given in Annex 4.

Table 20. The current acesulfame K intake from other sources among adults (mg/kg bw/day)

	Mean	Median	95th percentile
Adults	0.04	0.03	0.14

9.2.2.3 *Exposure to acesulfame K from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (50% scenario)*

The acesulfame K intake was estimated with the assumption that half of the consumed soft drinks, 'saft' and nectar contain acesulfame K at the average level reported by industry (weighted average content). The estimated acesulfame K intake in the 50% scenario was highest for the 1- and 2-year-old children, with an intake within the 95th percentile of 3.2 and 3.5 mg/kg bw/day, respectively (Table 21 and Figure 19).

Table 21. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	883	1.0	0.6	3.2
2-year-old	1487	1.1	0.7	3.5
4-year-old	283	0.8	0.7	1.8
9-year-old	669	0.7	0.6	1.5
13-year-old	841	0.6	0.5	1.3
Men	1067	0.3	0.2	1.0
Women	1134	0.3	0.1	0.9

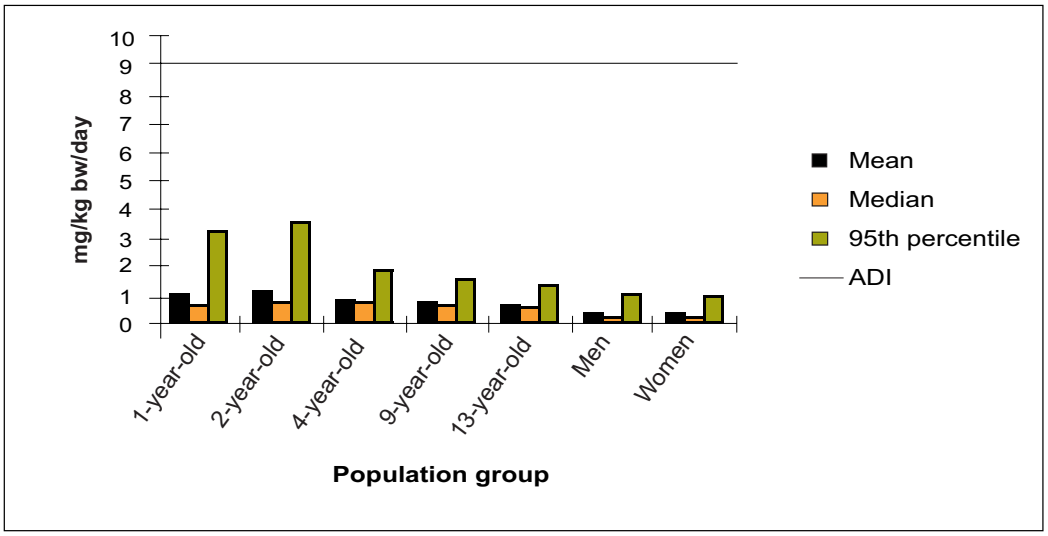


Figure 19. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.2.2.4 Exposure to acesulfame K from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (100% scenario)

The acesulfame K intake was estimated with the assumption that all consumed soft drinks, 'saft' and nectar contain acesulfame K at the average level reported by the industry. The acesulfame K intake was highest for 1- and 2-year-old children, with an intake within the 95th percentile of 6.4 and 7.1 mg/kg bw/day, respectively (Table 22 and Figure 20).

Table 22. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	883	1.9	1.1	6.4
2-year-old	1487	2.3	1.4	7.1
4-year-old	283	1.6	1.4	3.7
9-year-old	669	1.4	1.3	3.0
13-year-old	841	1.1	1.0	2.6
Men	1080	0.6	0.3	2.1
Women	1151	0.5	0.3	1.7

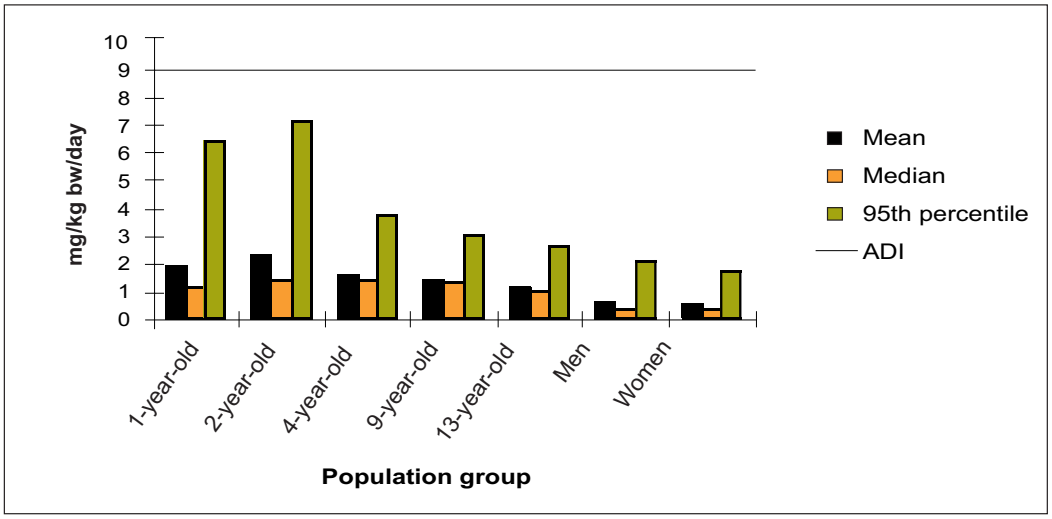


Figure 20. Intake of acesulfame K among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.2.2.5 *Previous reports of intake of acesulfame K in European countries*

A consumer survey was carried out among Italian female teenagers who regularly consume soft drinks and table top sweeteners. For detailed description, see section 9.1.2.5. The intake of acesulfame K in a worst-case scenario calculated at the 95th percentile was reported to be 3.6 mg/kg bw for female teenagers with a high consumption of sugar-free soft drinks (Arcella *et al*., 2004).

A survey of intense sweeteners, including acesulfame K, was performed among the Dutch population. For detailed description, see section 9.1.2.5. The intake of acesulfame K in the worst-case scenario was highest for 1- to 4-year-old children (consumers only) with a reported intake of 6 and 3 mg/kg bw/day from soft drinks and squashes, respectively (van Rooij-van den Bos *et al*., 2004).

The intake of intense sweeteners from soft drinks among British children (n = 1110), 1.5- to 4.5–year-old, was estimated in a 7-days dietary survey published by the Food Standard Agency (FSA) in 2003. For detailed description, see section 9.1.2.5. For the high consumers (97.5th percentile) the acesulfame K intake was estimated to 3.72 mg/kg bw/day (FSA, 2003).

An intake estimate of additives in the European Community was published in 2001, based on intake surveys from several European countries including Norway. A tiered approach was used were the intake estimate at tier 1 was based on theoretical food consumption data combined with the maximum permitted usage levels, tier 2 on actual national food consumption data combined with the maximum permitted usage levels, and tier 3 on actual national food consumption data combined with the actual usage levels. Only additives for which the intake exceeded the ADI on one tier were examined further at the next tier. The intake estimates were performed for adults and young children (below 3 years) based on the average consumption in the whole population, without taking into account the high consumers. No Member States submitted complete information on tier 3 results. An intake of acesulfame K from 2.7 to 9.6 mg/kg bw/day at tier 2 was reported for young children. It was concluded that an examination of intakes for young children at tier 3 is needed (COM, 2001).

The estimated intake of sweeteners, including acesulfame K, in persons with diabetes was performed in a Swedish study. For detailed description, see section 9.1.2.5. In a worst-case calculation based on the 10 or 20 children with highest intake of beverages, an acesulfame K intake of 15.2 and 11.2 mg/kg bw/day was reported, respectively. However, it is assumed that this is an overestimated intake for acesulfame K since the industry probably uses lower levels of acesulfame K in their beverages (Ilbäck *et al*., 2003).

A pilot survey of the intake of intense sweeteners in 1- to 19-year-old children with diabetes (n = 191) was performed by the Norwegian Food Control Authority in 2000. For detailed description, see section 9.1.2.5. The intake of acesulfame K within the 90th percentile was estimated to 2.9 and 0.8 mg/kg bw/day for the diabetic and control group, respectively (Drøpping, 2003).

A similar study in young insulin-dependent diabetics (n = 227) was performed in France. For detailed description, see section 9.1.2.5. At the 97.5th percentile, an acesulfame K intake of 4.0 mg/kg bw/day was reported for consumers only (Garnier-Sagne *et al*., 2001).

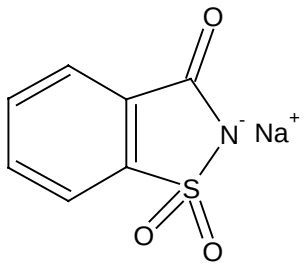
9.2.3 Risk characterisation of acesulfame K intake

For acesulfame K an ADI of 0-9 mg/kg bw/day was allocated by SCF in 1984 and maintained in an opinion from 2000.

In the 100% scenario, where all consumed soft drinks, 'saft' and nectar are assumed to contain acesulfame K at the average level reported by the industry, the group with the highest estimated intake of acesulfame K, 2-year-old children, will have an intake within the 95th percentile of 79% of the ADI for acesulfame K. The intake from other possible sources has not been included in this estimate.

This indicates that young children might be at risk for having an acesulfame K intake close to or above ADI depending on the intake from other sources. This is in line with the observed acesulfame K intake reported in the Netherlands and other European countries. At the moment no intake data for acesulfame K from other sources than soft drinks, 'saft' and nectar are available for children.

9.3 Saccharin (E954)



Sodium saccharin

Saccharin was discovered as early as 1880 and has been used as a intense sweetener in food for more than 100 years (Zinck and Hallas-Møller, 1996).

9.3.1 Hazard characterisation of saccharin

9.3.1.1 Evaluations by SCF/EFSA

Saccharin has been evaluated by SCF in 1977, 1984, 1988 and in 1995. In 1977 a temporary ADI of 0-2.5 mg/kg bw was allocated, although it was concluded that there was a need for more detailed purity criteria and specifications (SCF, 1977). The temporary ADI was maintained in 1984 while waiting for mechanistic studies of the carcinogenic effect of saccharin on urinary bladder cancer development in male rats (SCF, 1985). SCF was informed about additional studies in 1988, but they considered that these studies were of such quality that a change in the temporary ADI was not required (SCF, 1989). In 1995, saccharin was re-evaluated by SCF and a full ADI of 0-5 mg/kg bw was allocated. The ADI was derived from a rat study with histophatological changes of the bladder tissue with a NOEL of 1% (500 mg/kg bw) in the diet and applying an uncertainty factor of 100. The male rat bladder seems to be especially susceptible to saccharin compared to man, mice, hamster and monkeys. In male rats increased urinary sodium content and a high urinary pH are essential for the promotion of the bladder epithelia (SCF, 1995).

9.3.1.2 Evaluations by other international or national bodies

JECFA has evaluated saccharin seven times, in 1967, 1974, 1977, 1980, 1982, 1984 and latest in 1993. Based on a long-term study in rats an unconditional ADI of 0-5 mg/kg bw and a conditional ADI of 0-15 mg/kg bw for dietetic purposes were allocated in 1968 (JECFA, 1968). In 1977 three carcinogenicity studies showed a significant increase in bladder tumours in the F_1 generation of male rats fed a dietary level of 5% saccharin or higher. Owing to concerns resulting from the new findings, JECFA changed the unconditional ADI from 0-5 mg/kg bw to a temporary ADI of 0-2.5 mg/kg bw and withdrew the conditional ADI of 0-15 mg/kg bw (JECFA, 1978). In 1980 and 1982, the temporary ADI was extended pending the completion of additional studies (JECFA, 1980b, 1982a). Saccharin was evaluated again by JECFA in 1984 based on new information on biochemistry, pharmacokinetic, carcinogenicity and epidemiology. Saccharin was concluded to be non-mutagenic, but a bladder carcinogen in rats when given at a dose of 3% or higher in the feed. The temporary ADI of 0-2.5 mg/kg bw was maintained, waiting for further data on bladder histopathology and elucidation of the mechanism by which saccharin produce bladder tumours (JECFA, 1984). In 1993, the last time JECFA evaluated saccharin, an ADI of 0-5 mg/kg bw was allocated based on a NOEL of 500 mg/kg bw/day in a recent 2-generation feeding study in rats. It was concluded that the hyperplastic and tumour-

promoting activity of saccharin on the urothelium in male rats are caused by increased urinary concentrations of sodium ions and elevated pH, as other organic anions have been shown to promote bladder carcinogenesis under the same conditions. The epidemiological studies on saccharin did not show any evidence that saccharin ingestion increases the incidence of bladder cancer in the human population (JECFA, 1993).

9.3.1.3 *Recent studies not included in previous evaluations*

New animal studies

Effects on the bladder
Twenty monkeys of 3 species (6 African green, 7 rhesus, 6 cynomolgus and 1 hybrid) were treated with sodium saccharin (25 mg/kg bw 5 days a week) in the diet beginning 24 hours after birth and continuing for up to 24 years. Sixteen monkeys (7 rhesus and 9 cynomolgus) served as controls. One- to two years before the animals were sacrificed, urine samples were collected from two female and 2 male monkeys treated with sodium saccharin and from the same number and gender of control animals. The urine was examined for the presence of calculi, microcrystals, and precipitate. After the sacrifice of the animals, full histophatological examination of the animals was performed. Urinary bladders were examined by light microscopy and scanning electron microscopy. Sodium saccharin treatment had no effect on the urothelium in any of the treated monkeys. There was no evidence of increased urothelial cell proliferation or formation of solid material in the urine (Takayama *et al*., 1998).

Mutagenicity
Groups of 10 male BigBlue rats were exposed for 10 days to 5% sodium saccharin in the diet, while the control animals were given feed without sodium saccharin. As a positive control BigBlue rats were given 20 mg/kg bw of 4-aminobiphenyl administered by gavage. After 14 days the animals were sacrificed and DNA were isolated from liver, kidney and bladder, and analysed for mutation in the *lacI* gene determined by the mutation frequency (MF) for each test group. There was no significant increase in MF in either liver or bladder after treatment with sodium saccharin. The positive control 4-aminobiphenyl gave significant increase in MF ($P < 0.01$-0.001) in liver, bladder and kidney (Turner *et al*., 2001).

Saccharin and sodium saccharin were given once orally to groups of 4 ddY mice and a comet assay was performed on the glandular stomach, colon, liver, kidney, urinary bladder, lung, brain and bone marrow 3 and 24 hours after treatment. The dose of saccharin given to the mice was unclear, but was presumed to be 0, 100, 1000 and 2000 mg/kg bw when sacrificed 3 hours after exposure, and 2000 mg/kg bw when scarified 24 hours after exposure for both saccharin and sodium saccharin. Significant positive response in the comet assay was observed in the stomach and colon after 3 hours with 1000 and 2000 mg/kg bw sodium saccharin and after 24 hours with 2000 sodium saccharin, and in the colon after 3 hours with 1000 and 2000 mg/kg bw saccharin, and after 24 hours with 2000 mg/kg bw saccharin. No positive response was found in the other organs tested (Sasaki *et al*., 2002). VKM noted that a possible cytotoxic effect in the affected tissue was not properly investigated.

Based on an overall evaluation and previous negative results in *in vivo* genotoxicity studies and a multi-generation feeding study in rats (JECFA, 1984, 1993), VKM concludes that saccharin is not genotoxic.

New *in vitro* studies

Mutagenicity
Isolated hepatocytes from male F344 and Sprague-Dawley rats were exposed to saccharin (0, 50, 100, and 200 mM) for 20 hours. DNA damage was measured by the primary rat hepatocyte/

DNA repair assay which measures autioradiographically incorporation of ^{3}H-thymidine into nuclei of non-replicating cultured hepatocytes. The test is considered valid when the solvent and negative control yield negative values for the net nuclear grain count (NNG) and the positive control yields positive NNG values. As positive control 10 μM 2-aminofluorene was used. Saccharin was found to be negative in the DNA repair assay (Jeffrey and Williams, 2000).

9.3.1.4 *Conclusion hazard characterisation of saccharin*

On the basis of the new toxicological data on saccharin it is not necessary to revise the existing ADI of saccharin of 0-5 mg/kg bw.

9.3.2 Exposure assessment of saccharin

The calculated exposure to saccharin from soft drinks, 'saft' and nectar has been based on actual content level used in soft drink, 'saft' and nectar and the sales volumes reported by the industry (weighted average content). Consumption data were taken from Norwegian dietary surveys among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

In the intake estimates where it is assumed that 50% and 100% of all consumed soft drinks, 'saft' and nectar contain intense sweeteners, the weighted average value for content of saccharin is used.

Although saccharin has been found in low amounts in energy reduced soft drinks, the intake estimates for all groups of consumers were estimated to zero, even when it was assumed that 100% of all soft drinks, 'saft' and nectar contained saccharin.

Intake data of saccharin from other sources than soft drinks, 'saft' and nectar are only available for adults. The total intake of saccharin has therefore not been calculated for children and adolescents. The estimated intake of saccharin for adults from other sources within the 95th percentile was 0.19 mg/kg bw.

9.3.2.1 *Previous reports of intake of saccharin in European countries*

The intake of saccharin from soft drinks and squashes is generally higher in other European countries compared to Norway, probably because more saccharin is used in these products in Europe (van Rooij-van den Bos *et al*., 2004).

A consumer survey was carried out among Italian female teenagers who regularly consume soft drinks and table top sweeteners. For detailed description, see section 9.1.2.5. The intake of saccharin at the worst-case scenario at the 95th percentile was reported to be 1.8 mg/kg/bw for female teenagers with a high consumption of sugar-free soft drinks (Arcella *et al*., 2004).

A survey of intense sweeteners, including saccharine, was performed among the Dutch population. For detailed description, see section 9.1.2.5. The intake of saccharin in the worst-case scenario was highest for 1- to 4-year-old children (consumers only) with a reported intake of 2 and 1 mg/kg bw/day from soft drinks and squashes, respectively (van Rooij-van den Bos *et al*., 2004).

The intake of intense sweeteners from soft drinks among British children (n = 1110), 1.5- to 4.5-year-old, was estimated in a 7-days dietary survey published by the Food Standard Agency (FSA) in 2003. For detailed description, see section 9.1.2.5. For the high consumers (97.5th percentile) the saccharin intake was estimated to 3.8 mg/kg bw/day (FSA, 2003).

A pilot survey of the intake of intense sweeteners in 1- to 19-year-old children with diabetes (n = 191), was performed by the Norwegian Food Control Authority in 2000. For detailed description, see section 9.1.2.5. The intake of saccharine within the 90th percentile was estimated to 0.4 and 0.2 mg/kg bw/day for the diabetic and control group, respectively (Drøpping, 2003).

An intake estimate of additives in the European Community was published in 2001, based on intake surveys from several European countries including Norway. For detailed description, see section 9.2.2.5. An intake of saccharin from 0.1 to 2.6 mg/kg bw/day at tier 2 was reported for young children. No further evaluation at tier 3 was needed for saccharin (COM, 2001).

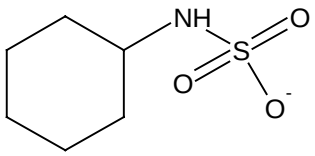
9.3.3 Risk characterisation of saccharin intake

For saccharin an ADI of 0-5 mg/kg bw was allocated by SCF in 1995.

In the 100% scenario, where all consumed soft drinks, 'saft' and nectar are assumed to contain saccharin at the average level reported by the industry, the intake of saccharin in all age groups were estimated to be zero. The intake of saccharin for adults from other sources were estimated to be 0.19 mg/kg bw within the 95th percentile, which corresponds to 3.8% of the ADI.

It is therefore concluded that it is unlikely that any age-groups in the Norwegian population are at risk of exceeding the ADI of 0-5 mg/kg bw for saccharin.

9.4 Cyclamate (E952)



Cyclamate

Cyclamate was discovered in 1937, and in USA it was designated generally recognised as safe (GRAS) in 1958. However, in 1969 cyclamate was disclaimed for use as a sweetener in most countries since experiments in rats suggested that cyclamate could be carcinogenic. Since then, most countries in EU have reapproved cyclamate for use in food and beverages.

9.4.1 Hazard characterisation of cyclamate

9.4.1.1 Evaluations by SCF/EFSA

Cyclamate has been evaluated by SCF in 1984, 1988, 1991, 1995 and in 2000. In 1984, a temporary group ADI for cyclamic acid and its sodium and calcium salts of 11 mg/kg bw/day was allocated based on a 90-days feeding study where rats were given cyclohexylamine, the toxic metabolite of cyclamate produced by microbial fermentation of unabsorbed cyclamate in the lower gut. A NOEL of 100 mg/kg bw was derived from the experiment with respect to testicular damage. The ADI received temporary status because of uncertainty about whether the testicular toxicity observed in rats was relevant for humans (SCF, 1985). New studies received by SCF in 1988 confirmed that cyclohexylamine was handled similarly by rat and man. The toxicological data obtained in rat were therefore valid for extrapolation to man, and the temporary ADI for cyclamates was maintained (SCF, 1989). SCF confirmed its existing temporary group ADI for cyclamates in 1991, but stated that there was a need for more information concerning to which degree cyclamate is converted to cyclohexylamine in humans before a full ADI could be established (SCF, 1992). In 1995, SCF maintained its temporary group ADI, pending submission of further data on conversion rates of cyclamate to cyclohexylamine in humans and *in vitro* studies which compare the relative sensitivity of human, monkey and rat testicular tissue to cyclohexylamine (SCF, 1997). New data on the conversion of cyclamate to cyclohexylamine in humans were submitted to SCF in 2000, eliminating the uncertainties related to the conversion rate. The maximum observed individual conversion rate was 85%. A full ADI for cyclamates of 0-7 mg/kg bw was established based on the toxicity of cyclohexylamine (SCF, 2000b).

9.4.1.2 *Evaluations by other international or national bodies*

JECFA has evaluated cyclamate in 1977, 1980 and 1982. A temporary ADI of 0-4 mg/kg bw was allocated in 1977 based on a study on testicular atrophy in rats given cyclohexylamine in the diet. The calculations were based on a NOEL of 74 mg/kg bw and the assumptions that 60% of the ingested cyclamate was available for conversion and that only 30% of cyclamate was converted to cyclohexylamine. This amount was then multiplied with the ratio of the molecular weight of cyclamic acid to cyclohexylamide. In addition a safety factor of 200 was used (JECFA, 1977). In 1980, the temporary ADI of cyclamate was maintained pending completion of a reproduction study and studies to establish the extent of conversion of cyclamates to cyclohexylamine in man (JECFA, 1980c). A full ADI of 0-11 mg/kg bw was allocated in 1982 based on new data and a NOEL of 100 mg/kg bw from a rat study given cyclohexylamine in the diet. Because of the new data, the safety factor was reduced to 100. The assumed conversion of cyclamate in the evaluation from 1977 was supported by the new data in humans showing that 63% of cyclamate was available for conversion and a conversion rate of 30% in humans (JECFA, 1982b).

9.4.1.3 *Recent studies not included in previous evaluations*

New human studies

Clinically defined infertile 30- to 50- year-old men (n = 405) and controls (n = 379) were surveyed to examine a possible relationship between the intake of cyclamate and male fertility in humans. Two samples of semen were obtained from all cases and one specimen was analysed from controls. A 24-hour urine sample was collected from each participant to analyse for cyclamate and cyclohexylamine content. Data on exposure to artificial sweeteners, and other independent factors such as education, smoking habits, physical activity, total energy intake and other variables, were obtained by comprehensive questionnaires. The questionnaire on cyclamate intake was validated in a subsample using cyclohexylamine and cyclamate in urine as indicators of the respective intake. No evidence was found of a significant association between cyclamate intake or cyclamate/cyclohexylamine excretion and male infertility (Serra-Majem *et al*., 2003).

New animal studies

Mutagenicity

Sodium cyclamate was given once orally to groups of 4 ddY mice and a comet assay was performed on the glandular stomach, colon, liver, kidney, urinary bladder, lung, brain and bone marrow. The concentration of sodium cyclamate given to the mice was unclear, but was presumed to be 0, 100, 1000 and 2000 mg/kg bw and the animals were sacrificed 3 or 24 hours after exposure. A significant positive response in the comet assay was observed at the highest cyclamate dose (2000 mg/kg bw) in the stomach after 3 hours and in colon, kidney and bladder after 24 hours. No positive response was found in the other organs tested (Sasaki *et al*., 2002).

VKM notes that a possible cytotoxic effect in the affected tissue is not properly investigated. In addition the endpoints measured in the comet assay are an indication of interaction with cellular DNA but are not necessarily associated with heritable genetic damage, which can initiate cancer. Since cyclamate did not induce cancer in rats and mice, it can be assumed that the primary DNA damage observed in mice after short-term exposure to high doses is repaired at lower doses.

New *in vitro* studies

Mutagenicity

Isolated hepatocytes from male F344 and Sprague-Dawley rats were exposed to sodium cyclamate (0, 20 and 40 mM) for 20 hours. DNA damage was measured by the primary rat hepato-

cyte/DNA repair assay which measures autioradiographically incorporation of ^{3}H-thymidine into nuclei of non-replicating cultured hepatocytes. The test is considered valid when the solvent and negative control yield negative values for the net nuclear grain count (NNG) and the positive control yields positive NNG values. As positive control 10 µg M 2-aminofluorene was used. Sodium cyclamate was found to be negative in the DNA repair assay (Jeffrey and Williams, 2000).

9.4.1.4 *Conclusion hazard characterisation of cyclamate*

On the basis of the new toxicological data on cyclamate it is not necessary to revise the existing ADI of cyclamate on 0-7 mg/kg bw.

9.4.2 Exposure assessment of cyclamate

The calculated exposure to cyclamate from soft drinks, 'saft' and nectar has been based on actual content level used in soft drink, 'saft' and nectar and the sales volumes reported by the industry (weighted average content). Consumption data were taken from Norwegian dietary surveys among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

In the intake estimates where it is assumed that 50% and 100% of all consumed soft drinks, 'saft' and nectar contain intense sweeteners, the weighted average value for the content of cyclamate is used.

Intake data of cyclamate from other sources than soft drinks, 'saft' and nectar are only available for adults. The total intake of cyclamate has therefore not been calculated for children and adolescents. Each table and figure shows the estimated mean daily intake, median daily intake and the daily intake on the 95th percentile.

9.4.2.1 *Exposure to cyclamate from soft drinks, 'saft' and nectar at the current level*

The estimated exposure to cyclamate from soft drinks, 'saft' and nectar at current levels of intake is shown in Table 23 and Figure 21. The calculated mean and median intake of cyclamate at the current level of intake were zero for all age groups. Only within the 95th percentile for 13-year-old children and for men the intake were estimated to be above zero with a calculated intake of 0.1 mg/kg bw/day.

Table 23. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar at the current level

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	33	0	0	0
2-year-old	186	0	0	0
4-year-old	22	0	0	0
9-year-old	101	0	0	0
13-year-old	116	0	0	0.1
Men	162	0	0	0.1
Women	274	0	0	0

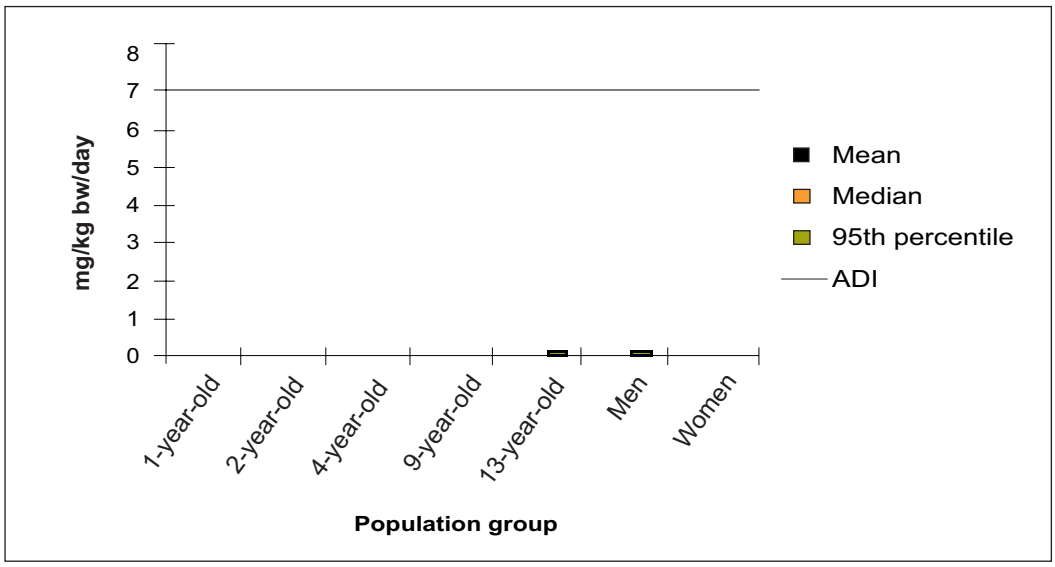


Figure 21. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar at the current level

9.4.2.2 *Current exposure of cyclamate from other sources*

The cyclamate intake from other sources, such as yoghurt, sweets, lozenges, chewing gum and table top sweeteners is based on analytical values of cyclamate from the different food categories, and it is calculated for a person weighting 60 kg (Table 24). The current intake of cyclamate from other sources among children and adolescents was not available. An overview of the authorised concentrations of cyclamate in different categories of foods is given in Annex 4.

Table 24. The current cyclamate intake from other sources among adults (mg/kg bw/day)

	Mean	Median	95th percentile
Adults	0.7	0.2	2.9

9.4.2.3 *Exposure to cyclamate from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (50% scenario)*

The cyclamate intake was estimated with the assumption that half of the consumed soft drinks, 'saft' and nectar contain cyclamate at the average level reported by industry (weighted average content). The estimated mean and median intakes of cyclamate were zero for all age groups. Only within the 95th percentile for men the intake was estimated to be above zero with an estimated intake of 0.1 mg/kg bw/day (Table 25 and Figure 22).

Table 25. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	50	0	0	0
2-year-old	697	0	0	0
4-year-old	154	0	0	0
9-year-old	520	0	0	0
13-year-old	685	0	0	0
Men	466	0	0	0.1
Women	437	0	0	0

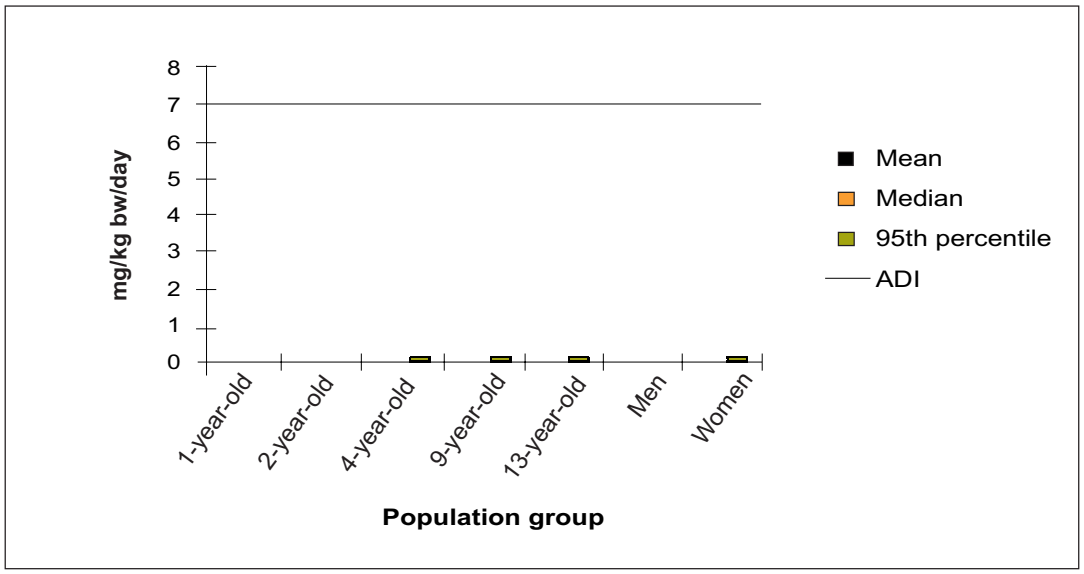


Figure 22. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.4.2.4 *Exposure to cyclamate from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (100% scenario)*

The cyclamate intake was estimated with the assumption that all consumed soft drinks, 'saft' and nectar contain cyclamate at the average level reported by the industry. The estimated mean and median intakes of cyclamate were zero for all age groups. Only within the 95th percentile for 4-, 9- and 13-year-old children and for women the intake were estimated to be above zero with an estimated intake of 0.1 mg/kg bw/day (Table 26 and Figure 23).

Table 26. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Number of consumers	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	159	0	0	0
2-year-old	133	0	0	0
4-year-old	192	0	0	0.1
9-year-old	584	0	0	0.1
13-year-old	752	0	0	0.1
Men	691	0	0	0
Women	666	0	0	0.1

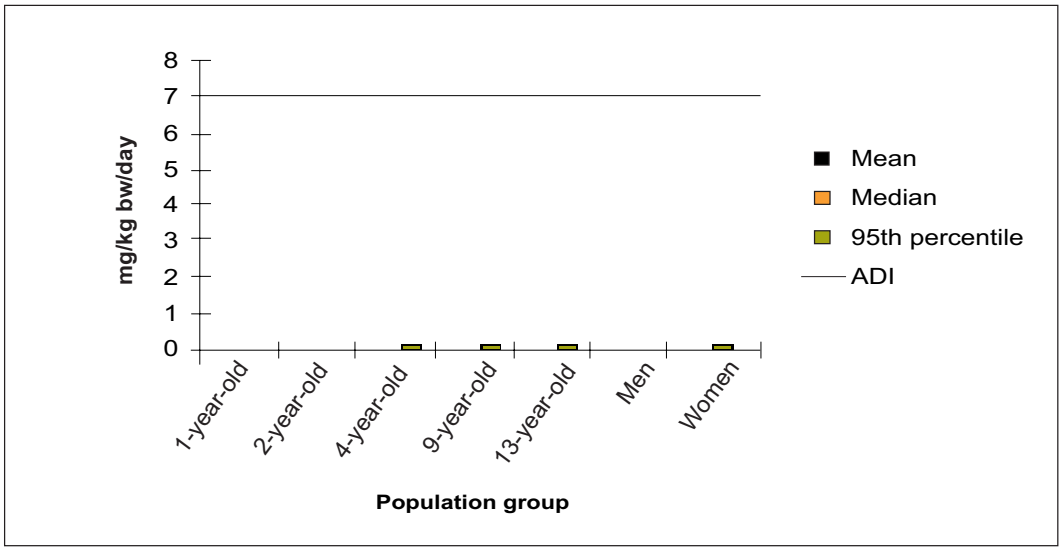


Figure 23. Intake of cyclamate among consumers only from soft drinks, 'saft' and nectar if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.4.2.5 Previous reports of intake of cyclamate in European countries

A consumer survey was carried out among Italian female teenagers who regularly consume soft drinks and table top sweeteners. For detailed description, see section 9.1.2.5. The intake of cyclamate in the worst-case scenario calculated at the 95th percentile was reported to be 3.7 mg/kg/bw for female teenagers with a high consumption of sugar-free soft drinks (Arcella *et al*., 2004).

A survey of intense sweeteners, including cyclamate, was performed among the Dutch population. For detailed description, see section 9.1.2.5. The intake of cyclamate in the worst-case scenario was highest for 1- to 4-year-old children (consumers only) with a reported intake of 14 and 13 mg/kg bw/day from soft drinks and squashes, respectively (van Rooij-van den Bos *et al*., 2004).

The intake of intense sweeteners from soft drinks among British children (n = 1110), 1.5- to 4.5–year-old, was estimated in a 7-days dietary survey published by the Food Standard Agency (FSA) in 2003. For detailed description, see section 9.1.2.5. For the high consumers (97.5th percentile) the cyclamate intake was estimated to 14.1 mg/kg bw/day (FSA, 2003).

The estimated intake of sweeteners, including cyclamate, in persons with diabetes was performed in a Swedish study. For detailed description, see section 9.1.2.5. In a worst-case calculation based on the 10 or 20 children with highest intake of beverages, a cyclamate intake on 28.9 and 21.2 mg/kg bw/day was reported, respectively. However, it is assumed that this is an overestimated intake for cyclamate since the industry probably uses lower levels of cyclamate in their beverages (Ilbäck *et al*., 2003).

A pilot survey of the intake of intense sweeteners in 1- to 19-year-old children with diabetes (n = 191), was performed by the Norwegian Food Control Authority in 2000. For detailed description, see section 9.1.2.5. The intake of cyclamate within the 90th percentile was estimated to 7.7 and 1.6 mg/kg bw/day for the diabetic and control group, respectively (Drøpping, 2003).

9.4.3 Risk characterisation of cyclamate intake

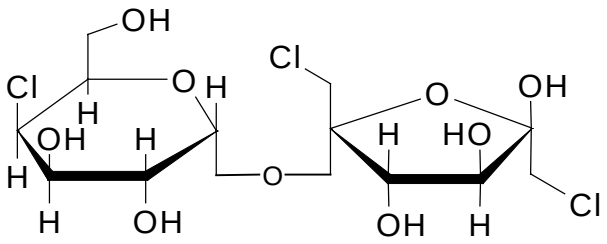
For cyclamate an ADI of 0-7 mg/kg bw/day was allocated by SCF in 2000.

In the 100% scenario, where all consumed soft drinks, 'saft' and nectar are assumed to contain cyclamate at the average level reported by the industry, 4-, 9- and 13-year-old children and

women will have an intake within the 95th percentile of 1.4% of ADI for cyclamate. The intake from other possible sources is not included in this estimate. However, an intake survey done by the Norwegian Food Control Authority in 1997 (Bergsten, 1998) showed that 97% of the intake of cyclamate came from consumption of table top sweeteners.

For children the intake of soft drinks, 'saft' and nectar contributes little to the intake of cyclamate, while the intake from other major sources is unknown. This might be a result of a history of different use of cyclamate in Norway compared to other countries in Europe.

9.5 Sucralose (E955)



Sucralose

Sucralose was first authorised for use in Canada in 1991. Subsequent authorisations came in Australia in 1993, in New Zealand in 1996 and in USA in 1998. Sucralose was authorised for use in the European Community in 2003 (dir 2003/116/EC) and in Norway on 13 May 2005.

9.5.1 Hazard characterisation of sucralose

9.5.1.1 Evaluations by SCF/EFSA

Sucralose (also known as 4, 1', 6' – trichlorogalactosucrose (TGS)) was evaluated by SCF in 1987 and further data were submitted in 1988. This intense sweetener was last evaluated by SCF in 2000. The first opinion by SCF was published in 1989. Earlier studies had established that orally administrated sucralose was poorly absorbed in mice, rats, rabbits, dogs and man. Amounts ranging from 8-22% were absorbed in man and the amount absorbed was excreted rapidly, essentially unchanged in urine. Following administration of single oral doses, the terminal elimination half-life was around 5, 25, 39 and 79 hours for rat, man, rabbit and dog, respectively. In 1989, SCF considered sucralose to be toxicologically unacceptable due to unresolved questions concerning some of the observed treatment related effects on body weight, organ weights and haematological parameters. It was unclear whether the effects observed in laboratory animals might be secondary to a cascade of events caused by impalatability of sucralose when given in the diet or might be due to a direct toxic action of sucralose itself (SCF, 1989).

In 2000, SCF published an opinion where further studies were considered regarding the concerns addressed by SCF in 1989. In addition SCF reviewed the earlier teratology studies again and a new rabbit teratology study, and considered the stability of sucralose, its metabolism and whether repeated administration might alter the activity of the gut microflora in response to reservations raised by the UK Committee on Toxicity (COT). SCF stated that there was adequate evidence, both for sucralose and for its hydrolysis products, that there were no concerns about mutagenicity, carcinogenicity, developmental or reproductive toxicity. Effects have been observed in some experimental animal studies on immune parameters, the gastro-intestinal tract and body weight gain. SCF concluded that sucralose is acceptable as a sweetener for general food use and allocated a full ADI of 0-15 mg/kg bw. The ADI was based on a NOEL of 1500 mg/kg bw from several studies in rats, where reduced body weight was found as the critical effect (SCF, 2000c).

9.5.1.2 *Evaluations by other international or national bodies*

JECFA evaluated sucralose in 1989 and 1991. In 1991, JECFA evaluated the effect of sucralose on pharmacokinetic, metabolism, mutagenicity, teratogenicity, reproduction, neurotoxicity, short-term, long-term and carcinogenicity, and found no adverse effects. In a teratogenicity study in rabbits, no effect was found on the foetus while a marked maternal toxicity was observed associated with severe disturbance in gastro-intestinal functions. This appears to be a non-specific effect in rabbits that are especially sensitive to non-absorbed compounds causing osmotic effects in the large bowl. Although TGS was poorly absorbed after oral administration and was not hydrolysed or dechlorinated, the toxicity of possible hydrolysis products from sucralose, e.g. 4-chloro-4-deoxygalactose (4-CG) and 1,6-dichloro-1,6-dideoxyfructose (1,6-DCF), was also evaluated. A temporary ADI of 0-3.5 mg/kg bw was allocated, but the study used as basis for the allocation was not notified. Further studies on metabolism in humans, effect on diabetics, possible bioaccumulation and effects on 6-chlorofructose were requested (JECFA, 1989). Sucralose was re-evaluated by JECFA in 1991, although only the requested studies on 6-chlorofructose were received.

New genotoxicity studies on 4-CG and 1,6-DCF, and studies on impalatability of sucralose were also evaluated. In the review of the new and old data, JECFA found that the data submitted were sufficient to allocate a full ADI of 0-15 mg/kg bw based on a NOAEL of 1500 mg/kg bw/day from a long-term study in rats. Although a slight reduction in body weight and organ weight were observed in this study compared to controls, this was judged to be caused by reduction of food intake as a result of impalatability of sucralose at this concentration. Additional immunotoxicity studies to assess the significance of observed weight changes in the spleen and thymus and changes in lymphocyte counts in rats were considered to be desirable (JECFA, 1991b).

9.5.1.3 *Recent studies not included in previous evaluations*

New human studies

The effect of daily administration of sucralose for 3 months on glycemic control was studied in subjects with type 2 diabetes. For a detailed description of the study see section *6.3.3*. This study demonstrates that sucralose consumption for 3 months of 7.5 mg/kg bw/day had no effect on glucose homeostasis in individuals with type 2 diabetes (Lee Grotz *et al*., 2003).

New animal studies

Sucralose was given once orally to groups of 4 ddY mice and a comet assay was performed on the glandular stomach, colon, liver, kidney, urinary bladder, lung, brain and bone marrow 3 and 24 hours after treatment. The dose of sucralose given to the mice was unclear, but was presumed to be 0 and 2000 mg/kg bw when sacrificed 3 hours after exposure and 0, 100, 1000 and 2000 mg/kg bw when sacrificed 24 hours after exposure. A significant positive response in the comet assay was observed in the stomach, colon and lung after 24 hours with 2000 mg/kg bw sucralose. No positive response was found in the other organs tested (Sasaki *et al*., 2002).

VKM notes that the genotoxic effect was only observed at a high exposure level and a possible cytotoxic effect in the affected tissue was not properly investigated. In addition the endpoints measured in the comet assay are an indication of interaction with cellular DNA, but not necessarily associated with heritable genetic damage, which can initiate cancer. Since sucralose did not induce cancer in rats and mice, it can be assumed that the primary DNA damage observed in mice after short-term exposure to high doses is repaired at lower doses. This hypothesis is also supported by the fact that sucralose did not induce micronuclei *in vivo* in mice and rats.

9.5.1.4 *Conclusion hazard characterisation of sucralose*

On the basis of the new toxicological data on sucralose it is not necessary to revise the existing ADI of sucralose of 0-15 mg/kg bw.

9.5.2 Exposure assessment of sucralose

The first products containing sucralose were introduced to the Norwegian market in 2005. Since the intake calculations are based on actual content of intense sweeteners, and sales volumes for 2004, it has not been possible to make any intake estimates for sucralose in this risk evaluation. However, products containing sucralose have been on the marked for several years in other European countries, and intake estimates of sucralose from some of these countries are referred to in this risk assessment.

9.5.2.1 Previous reports on intake of sucralose

The Food Safety Authority of Ireland (FSAI) has carried out a surveillance study on products containing sucralose. Twenty-nine samples comprising of flavoured water, soft drinks, alcoholic drinks, shakes, breakfast bars and other confectionaries were analysed for sucralose content in 2004-2005. The measured sucralose levels in soft drinks were between 8.4 and 285 mg/l, and below the maximum permitted dose of 300 mg/l. The North:South Ireland Food Consumption Survey (NSIFCS) (n = 1379) conducted from 1997-1999 was used to estimate the intake in the adult Irish population (18–64 year-olds). The estimated average intake of sucralose among the Irish adult population was 0.0307 mg/kg bw/day (0.190 mg/kg bw/day and 0.352 mg/kg bw/day for the 95th percentile and 97.5th percentile consumers, respectively) (FSAI, 2005).

In 2001, the UK Food Standards Agency estimated the intake of sucralose among adults and children. The intake estimates were based on the conservative assumption that all foodstuffs, whether energy-reduced or not, contained sucralose at the quoted level. Food consumption data from the "Diet and Nutrition Survey" of British Adults (1986/87) and the "National Diet and Nutrition Survey" of Children, aged 1.5-4.5 years, (1992/93) were used in the intake estimates. On a body weight basis, the overall adult mean intakes were estimated to be 2.1 mg/kg bw/day (7.6 mg/kg bw/day for the 97.5th percentile). For children, the main contributor to the overall intake of sucralose was soft drinks. The estimated 97.5th percentile for water-based drinks was estimated to be 17.4 mg/kg bw/day. However, this intake estimate was based on the unlikely scenario that all soft drinks consumed by children contain sucralose at the maximum level and are likely to be overestimates of the true values (FSA, 2001).

A study on consumption of intense sweeteners in Australia and New Zealand was published in 2005 by Food Standards Australia New Zealand (FSANZ). The study comprised 3 survey groups in both Australia and New Zealand; a national telephone survey (n = 3529), a 7-days diary survey of potentially high consumers (n = 400) and a supplementary diary survey of people with diabetes or impaired glucose tolerance (n = 298) performed in 2002-2003. A commercial-in-confidence database of the intense sweetener content of all the individual brand products was made in co-operation with manufacturers. Exposure to the individual sweeteners was estimated by using food consumption data in combination with the content of intense sweeteners in the products from the database. The calculated mean daily exposure to sucralose across both Australia and New Zealand for consumers was estimated to 34 mg/day (0.57 mg/kg bw/day for a person weighting 60 kg). The estimated intake of sucralose at the 95th percentile was 188 mg/day (3.1 mg/kg bw/day for a person weighting 60 kg) and 162 mg/day (2.7 mg/kg bw/day for a person weighting 60 kg) in Australia and New Zealand, respectively (FSANZ, 2003).

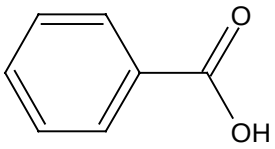
9.5.3 Risk characterisation of sucralose intake

No intake estimates of sucralose are available for the Norwegian population, and it is not possible to perform a risk assessment for sucralose at this stage. However, the intake estimates of sucralose from Australia, New Zealand, and Ireland were well below ADI for adults. Intake estimates for children were not performed. In the British study the intake of sucralose for high consumers among children were estimated to 17.4 mg/kg bw/day. This is probably an unrealistic high intake estimate, and not relevant for the Norwegian children since sucralose only recently has been introduced to the Norwegian market. The intake of sucralose for adults and children at the moment is most probably well below ADI. However, it cannot be excluded that future use of

sucralose in an increasing number of products can lead to intake levels above ADI. An overview of the authorised concentrations of sucralose in different categories of foods is given in Annex 4.

A full risk assessment of sucralose can only be performed when reliable intake estimates are available.

9.6 Benzoic acid, sodium benzoate, potassium benzoate and calcium benzoate (E210, E211, E212, E213)



Benzoic acid

Benzoic acid and its salts are some of the most used preservatives in food and drinks. It also occurs naturally in certain berries like lingonberries and cloudberries. Benzoic acid is also produced in the body from some of the amino acids.

In the following risk assessment the general term benzoic acid will also include the sodium, potassium and calcium benzoates. When referring to toxicity studies the specific compound studied will be referred. Benzyl acetate, benzyl alcohol and benzyl aldehyde are all metabolised to benzoic acid *in vivo*, and the toxicity tests performed with these and the benzoates may be applied also for evaluation of benzoic acid and its salts.

9.6.1 Hazard characterisation of benzoic acid and benzoates

9.6.1.1 Evaluations by SCF/EFSA

Benzoic acid and its salts were evaluated by SCF in 1994 and 2002 (SCF, 1994, 2002b). In addition benzyl alcohol was evaluated by SCF in 2002 (SCF, 2002c). In 1994, a temporary ADI of 0-5 mg/kg bw was given for the sum of benzoic acid and its salts based on a NOEL of 500 mg/kg bw taken from the long-term and multigeneration studies. The ADI was made temporary because benzoic acid was observed to be clastogenic *in vitro* and because of the observed glycine depletion in humans and animals administered large doses of benzoic acid (SCF, 1994). Additional studies on teratogenicity and clastogenic activity of benzoic acid *in vivo* were requested and later evaluated by SCF in 2002. The studies on teratogenicity were sufficient to conclude on an absence of a teratogenic potential, with an overall NOAEL for developmental toxicity of 500 mg/kg bw/day, based on effects on foetal weight. All the results from the *in vivo* genotoxicity studies were negative. On the basis of the new data, SCF established a full ADI of 0-5 mg/kg bw for benzoic acid and its salts, including benzyl alcohol and related benzyl derivatives used as flavourings (SCF, 2002b). Benzyl alcohol is used as a carrier solvent for flavourings, and was evaluated by SCF in a separate opinion in 2002. SCF concluded that the toxicity of benzyl alcohol has been studied extensively. Taking into account the toxicity data and the fact that benzyl alcohol is metabolised via benzaldehyd to benzoic acid, SCF confirmed the inclusion of benzyl alcohol in the group ADI of 0-5 mg/kg bw for benzoic acid and benzoates. It is assumed that ADI should be expressed as benzoic acid equivalents although not specifically stated by SCF in the opinion of 2002 (SCF, 2002c).

9.6.1.2 Evaluations by other international or national bodies

Benzoic acid and its salts were evaluated by JECFA in 1974 and an ADI of 0-5 mg/kg bw were allocated based on a NOAEL of 500 mg/kg bw from a long-term 4-generation rat study. This dose was the highest tested in this study and gave no effects on growth, fertility, lactation or

life-span. The post-mortem examination showed no abnormalities (JECFA, 1974). JECFA performed a full re-evaluation of the toxicity of benzyl acetate, benzyl alcohol, benzaldehyde, and benzoic acid and its salts together in one opinion in 1996. These compounds have previously been evaluated separately by JECFA, where it was recommended a full review of the substances together with special attention on reproductive and developmental toxicity. JECFA stated that the formation of hippuric acid from benzoic acid is a saturable process in which the availability of glycine is the rate-limiting step. Depletion of glycine might be of concern with respect to the developing foetus and neonate. However, developmental effects such as delays and reduced foetal and postnatal pup body weights were observed only at doses that were maternally toxic. JECFA concluded that there was no evidence for carcinogenic, developmental and reproductive toxicity. The group ADI of 0-5 mg/kg bw as benzoic acid equivalents was maintained (JECFA, 1996).

In 2000, WHO published a report which evaluated the effects of benzoic acid and sodium benzoate on human health. They concluded that the exposure to benzoic acid and sodium benzoate gave no indication of adverse reproductive or developmental effects. An *in vivo* dominant lethal assay with sodium benzoate gave positive results (IPCS, 2000). However, sodium benzoate was negative in 3 other *in vivo* genotoxicity tests (host-mediated assay, chromosome aberration test and dominant lethal assay) and 2 long-term carcinogenicity studies gave no indication of a carcinogenic effect of benzoic acid and sodium benzoate (SCF, 2002b).

9.6.1.3 Recent studies not included in previous evaluations

New human studies

In 2004, a study was published where the aim was to determine whether artificial food colourings and the preservatives benzoates in the diet of 3-year-old children in the general population influence hyperactive behaviour. A sample of 1873 children were screened in their fourth year for the presence of hyperactivity (HA) at baseline, of whom 1246 had skin prick tests to identify atopy (AT). Children were divided into four groups; HA/AT, not-HA/AT, HA/not-AT and not-HA/not-AT. After baseline assessment, children were subjected to a diet eliminating artificial colourings and benzoate preservatives for one week. The following 3 weeks the children received in random order, periods of dietary challenge with a drink containing artificial colourings (20 mg daily) and sodium benzoate (45 mg daily) (active period), or a placebo mixture, supplementary to their diet in a double-blind crossover study. Behaviour was assessed by a tester blind to dietary status or by parents' ratings. During the withdrawal periods a reduction in hyperactivity was observed, which were expected since the parents were not blind to the withdrawal. Both placebo and active challenge gave a significant increase in hyperactivity on parental reports, although the increase during active challenge was higher than placebo. These effects were independent of the presence or absence of hyperactivity or atopy. There were no significant differences detected based on objective testing in the clinic (Bateman *et al.,* 2004).

A pharmacokinetic study of sodium phenylacetate/sodium benzoate was performed in 2 groups of normal healthy volunteers, following infusion of the dose regimen used to treat hyperammonemia. The first group of subjects (n = 3) received a bolus dose of 5.5 g/m^2 (equivalent to 150 mg/kg bw) of sodium phenylacetate/sodium benzoate, over a period of 1.5 hours. Following a 7-days washout, subjects then received the same bolus dose followed by a continuous infusion of 5.5 g/m^2 over 24 hours. A second group of different subjects (n = 17) received the same treatment regimen, but using doses of 3.75 g/m^2 (equivalent to 100 mg/kg bw). Plasma levels of phenylacetate and benzoate, and their respective metabolites phenylacetylglutamine and hippurate were measured over a 24-hour period. Benzoate displayed a saturable and non-linear elimination, with decrease in clearance with increasing dose. Benzoate plasma levels immediately fell following the priming dose, and became undetectable at 14.1±4.2 and 26.8±2.3 hours in the low- and high-dose group, respectively. However, for benzoate the metabolite formation increased in a linear fashion with the dose (MacArthur *et al.*, 2004).

9.6.1.4 *Formation of benzene from benzoic acid and ascorbic acid*

Benzene has been detected at low levels in some soft drinks containing sodium benzoate and ascorbic acid (vitamin C). Sodium benzoate is added as a preservative and vitamin C may be used as an antioxidant or be naturally present. Benzene is both mutagenic and carcinogenic to humans. Benzene is an *in vivo* mutagen in mammals, where especially chromosomal aberrations and micronuclei are induced. There is also sufficient evidence to assume a causal relationship between high levels of cumulative benzene exposure and non-lymphatic leukaemia in humans. However, for all exposure scenarios the most relevant contribution to the total daily dose is the uptake via air, which contributes with 96 - > 99%. The contribution from drinking water and fish consumption vary in the range of 0.1-2%, and all other sources of exposure (milk, meat and vegetables) can be regarded as non-significant.

No tolerable intake of benzene in food has been established. In 1999, SCF expressed an opinion on certain aromatic hydrocarbons present in food. In the conclusion it was stated that SCF considered it unlikely that the intake of benzene from food at the contamination levels reported would contribute to an increased risk of cancer (SCF, 1999).

9.6.1.5 *Benzoic acid and hypersensitivity*

Benzoates are widely used as preservatives. Numerous case reports of adverse reactions to benzoates have been recorded, but most of the reports are lacking in control subjects, placebo controls and blinding. The reports consist of symptoms such as urticaria, asthma, rhinitis, eczema and one single report of anaphylaxis following oral, dermal or inhalation exposure to benzoates. The report on anaphylaxis was confirmed by double blind challenge (Michils *et al*., 1991).

Two well-controlled case reports with double blind placebo controlled design have been published by Asero (Asero, 2001, 2002) where sodium benzoate was found to be the substance causing rhinitis.

Two other well-conducted studies report on chronic rhinitis and acute urticaria/angio-oedema aggravated, but not caused, by food additives. Among these was sodium benzoate. Twenty of 226 patients with chronic rhinitis were sodium benzoate challenge positive, i.e. sodium benzoate was considered to aggravate their symptoms (Pacor *et al*., 2004). One of 47 subjects with recurrent episodes of urticaria/angio-oedema thought to be caused by food additives, experienced a reaction upon double blind placebo controlled challenge with sodium benzoate (Nettis *et al*., 2004).

There are reports on food additives and hyperactivity in preschool children, but challenges are performed with mixtures of additives such as preservatives and colourings. Hence, the effect of one additive alone is not possible to evaluate.

Hypersensitivity reactions to benzoates have been documented, but only rarely. None of the reactions were IgE mediated or considered immunologic reactions. Hence, they are not allergic. The term non-immunological hypersensitivity is therefore appropriate. The mechanisms are not well documented, but considered pharmacological, i.e. due to release of histamine from mast cells and/or basophils.

9.6.1.6 *Conclusion hazard characterisation of benzoic acid and benzoates*

On the basis of the new toxicological data on benzoic acid it is not necessary to revise the existing group ADI of benzoic acid and its salts of 0-5 mg/kg bw.

9.6.2 Exposure assessment of benzoic acid and benzoates

The calculated intake of benzoic acid from soft drinks, 'saft' and nectar has been based on actual content level used in soft drink, 'saft' and nectar and the sales volumes reported by the industry (weighted average content). Consumption data were taken from Norwegian dietary surveys

among children at the age of 1, 2, 4, 9 and 13 years, and among adults (Spedkost 1998/99, Småbarnskost 1998/99, Ungkost 2000, Norkost 1997).

For benzoic acid, the content in other foods than soft drinks, 'saft' and nectar is based on either analytical values, information from food manufacturers and in a few cases the upper authorised use level in food (Bergsten, 2000). Annex 2 shows the concentration of benzoic acid in other foods included in the exposure assessment of benzoic acid.

When sugar in soft drinks is replaced by intense sweeteners, the preservative effect of sugar is also removed. One possibility could be that the manufacturers add more benzoic acid in order to achieve sufficient preservation of the product. Therefore, an estimate was undertaken of the intake of benzoic acid in the scenario where it is assumed that 50% and 100%, respectively of all consumed soft drinks, 'saft' and nectar are sweetened with intense sweeteners. As for the intense sweeteners, a weighted average value is used in the intake estimates of benzoic acid.

SCF stated that it should be noted that the intake of benzyl alcohol and benzoic acid can result from different sources, and it is therefore possible that in some instances the intake of these substances may exceed the group ADI. Better data are required on use/residual levels following use of benzyl alcohol as a carrier solvent in different food categories (SCF, 2002c).

9.6.2.1 Total intake of benzoic acid and intake of benzoic acid from soft drinks, 'saft' and nectar at the current level

The estimated mean total intake of benzoic acid and the mean intake of benzoic acid from soft drinks, 'saft' and nectar at current levels of intake are shown in Table 27 and Figure 24. One-to-nine-year-old children were found to have the highest mean total intake (1.9 – 2.1 mg/kg bw/day) of benzoic acid at current level. Although the total current intake of benzoic acid was lower for women, they had the highest mean intake of benzoic acid from soft drinks, 'saft' and nectar (1.0 mg/kg bw/day). This accounted for 62.5% of the total intake of benzoic acid for women. For 1- to 9 year-old children the contribution from soft drinks, 'saft' and nectar accounted for 37% to 43% of the total intake of benzoic acid.

Table 27. The mean total benzoic acid intake and mean intake of benzoic acid from soft drinks, 'saft' and nectar at the current level

Age/sex	Total mean intake (mg/kg bw/day)	Mean intake from soft drinks, 'saft' and nectar (mg/kg bw/day)
1-year-old	1.9	0.7
2-year-old	2.1	0.9
4-year-old	2.0	0.8
9-year-old	1.9	0.7
13-year-old	1.7	0.6
Men	1.3	0.6
Women	1.6	1.0

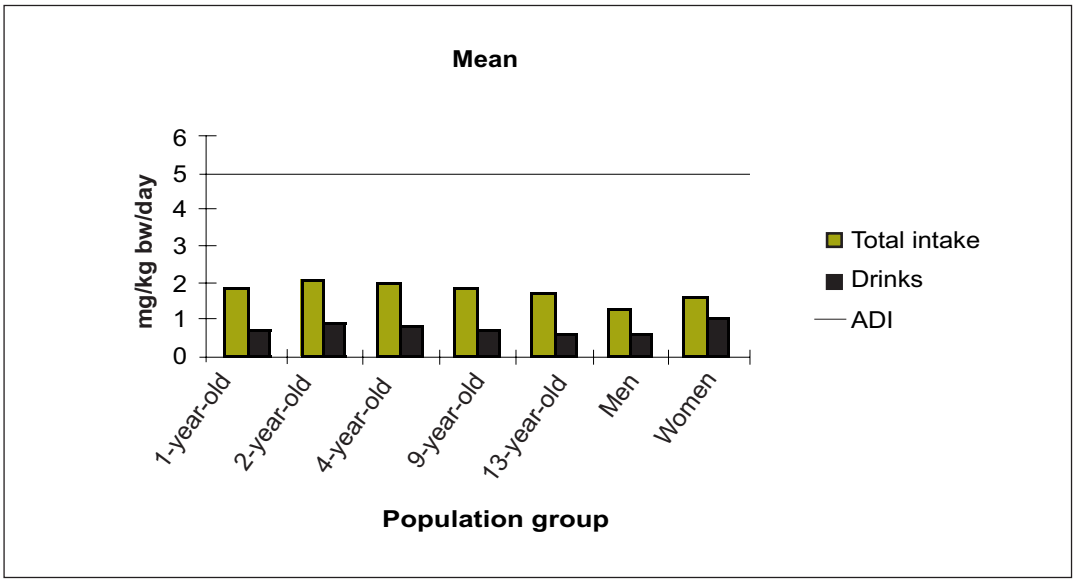


Figure 24. The mean total benzoic acid intake and mean intake of benzoic acid from soft drinks, 'saft' and nectar among consumers only at the current level

When the median total intake is estimated, 2- to 9-year-old children had the highest intake of benzoic acid (1.6 – 1.7 mg/kg bw/day). They also had the highest median intake of benzoic acid from soft drinks, 'saft' and nectar (0.6 mg/kg bw/kg). The median intake from soft drinks, 'saft' and nectar was estimated to be between 0.4 to 0.6 mg/kg bw/day for all age groups. The intake from soft drinks, 'saft' and nectar contributed to 30.7-45.5% of the total intake of benzoic acid. Women had the highest percentage intake (45.5%) of benzoic acid from soft drinks, 'saft' and nectar (Table 28 and Figure 25).

Table 28. The median total benzoic acid intake and median intake of benzoic acid from soft drinks, 'saft' and nectar among consumers only at the current level

Age/sex	Total median intake (mg/kg bw/day)	Median intake from soft drinks, 'saft' and nectar (mg/kg bw/day)
1-year-old	1.3	0.4
2-year-old	1.7	0.6
4-year-old	1.7	0.6
9-year-old	1.6	0.6
13-year-old	1.3	0.5
Men	1.0	0.4
Women	1.1	0.5

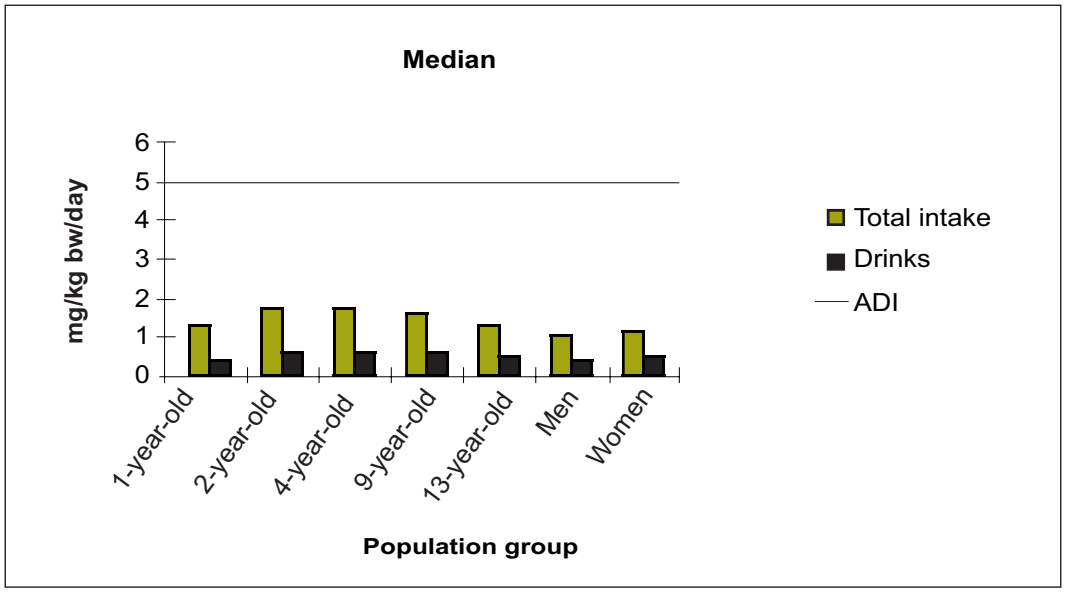


Figure 25. The median total benzoic acid intake and median intake of benzoic acid from soft drinks, 'saft' and nectar among consumers only at the current level

The total intake of benzoic acid at the current level within the 95th percentile was highest for 1-year-old children and estimated to be 5.5 mg/kg bw/day. The intake of benzoic acid from soft drinks, 'saft' and nectar contributed to 41.8% of the total intake for this age group. Women had the highest intake of benzoic acid from soft drinks, 'saft' and nectar (3.9 mg/kg bw/day), contributing to 90.7% of the total intake. The results from intake estimates of benzoic acid at the current level showed that intake of benzoic acid from other food products were equally important as soft drinks, 'saft' and nectar for the children with a high intake of benzoic acid. For men and women, the high intake of benzoic acid within the 95th percentile was mainly caused by a high intake of soft drinks, 'saft' and nectar (Table 29 and Figure 26). An overview of the authorised concentrations of benzoic acid and benzoates in different categories of foods is given in Annex 5.

Table 29. The total benzoic acid intake and intake of benzoic acid from soft drinks, 'saft' and nectar within the 95th percentile among consumers only at the current level

Age/sex	Total intake (mg/kg bw/day)	Intake from soft drinks, 'saft' and nectar (mg/kg bw/day)
1-year-old	5.5	2.3
2-year-old	4.8	2.8
4-year-old	4.7	1.8
9-year-old	4.4	1.5
13-year-old	4.2	1.6
Men	3.0	2.1
Women	4.3	3.9

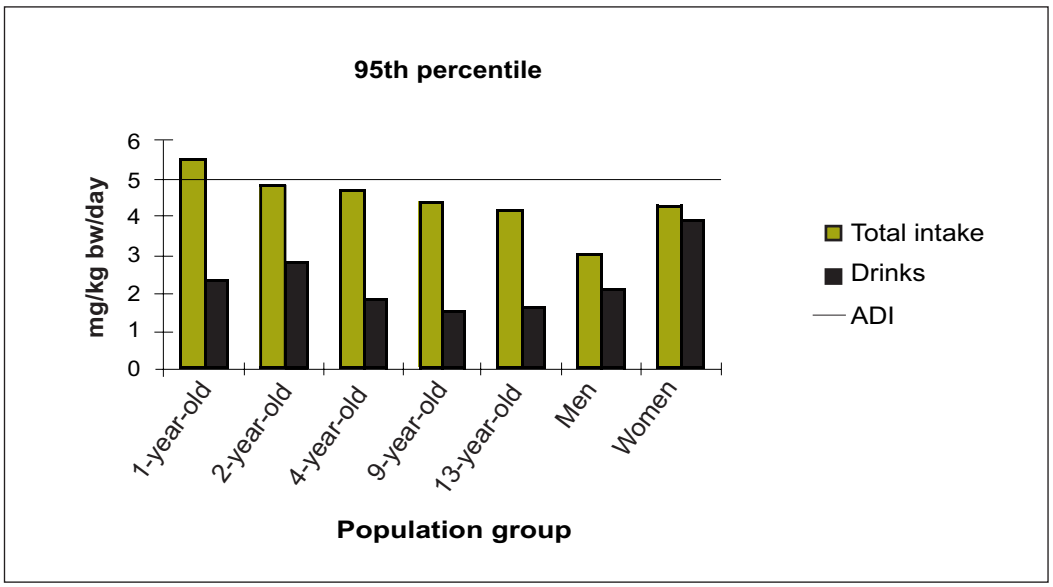


Figure 26. The total benzoic acid intake and intake of benzoic acid from soft drinks, 'saft' and nectar within the 95th percentile among consumers only at the current level

9.6.2.2 Total intake of benzoic acid if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (50% scenario)

The estimated total intake of benzoic acid among consumers only if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners is shown in Table 30 and Figure 27.

Table 30. The total benzoic acid intake if 50% of soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	1.9	1.3	5.8
2-year-old	2.2	1.8	5.0
4-year-old	2.2	1.9	4.7
9-year-old	2.2	1.8	4.9
13-year-old	1.9	1.6	4.6
Men	1.4	1.1	3.4
Women	1.6	1.1	4.5

The highest estimated intake of benzoic acid within the 95th percentile was found for 1- and 2-year-old children, with an intake of 5.8 and 5.0 mg/kg bw/day, respectively. If it is assumed that 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners, a slight increase in the intake of benzoic acid for high consumers (95th percentile) was estimated (0.2 – 0.5 mg/kg bw/day) compared with the current intake (Table 29).

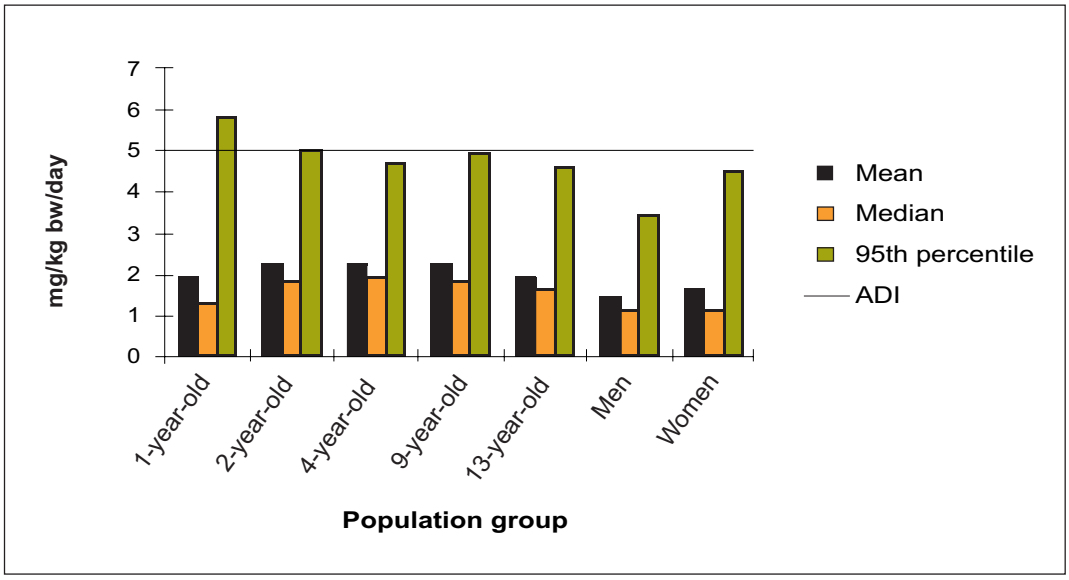


Figure 27. The total benzoic acid intake if 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.6.2.3 *Total intake of benzoic acid if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (100% scenario)*

The estimated total intake of benzoic acid among consumers only when 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners is shown in Table 31 and Figure 28.

Table 31. The total benzoic acid intake if 100% of soft drinks, 'saft' and nectar contain intense sweeteners

Age/sex	Mean (mg/kg bw/day)	Median (mg/kg bw/day)	95th percentile (mg/kg bw/day)
1-year-old	2.0	1.3	5.9
2-year-old	2.3	1.9	5.2
4-year-old	2.4	2.1	5.2
9-year-old	2.5	2.1	5.6
13-year-old	2.3	1.9	5.3
Men	1.6	1.2	4.2
Women	1.7	1.2	4.9

When it is assumed that 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners, the highest mean intake was found among 4- and 9-year-old children with an estimated intake of 2.4 and 2.5 mg/kg bw/day, respectively. Among the high consumers (95th percentile) the highest intake was found within the 1- and 9-year-olds with intakes of 5.9 and 5.6 mg/kg bw/day, respectively. Comparing benzoic acid intake when 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners with current intake (Table 29), an increase in the total intake of benzoic acid among high consumers (95th percentile) was estimated for all age groups (0.4 – 1.2 mg/kg bw/day). The largest increase in benzoic acid intake was found for 9- and 13-year-old children and men, the same groups where the consumption of soft drinks, 'saft' and nectar contributed least to the benzoic acid intake at the current level (Table 29).

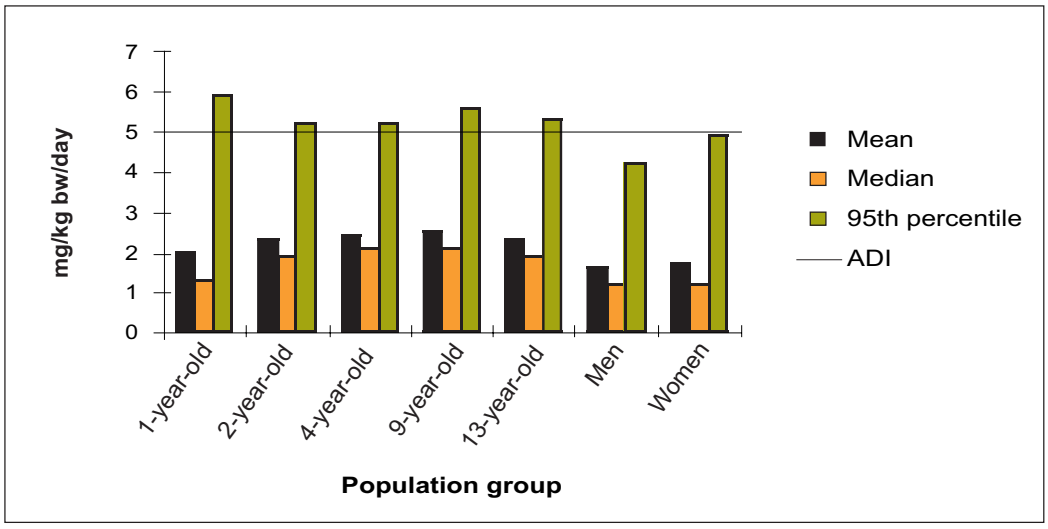


Figure 28. The total benzoic acid intake if 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners

9.6.2.4 Previous reports of intake of benzoic acid

A report on the intake of benzoic acid and sorbic acid in Norway was published by the Norwegian Food Control Authority (SNT) in 2000 (Bergsten, 2000). This report only includes adults divided in different age groups and 13-year-old children. An analytical survey was performed to determine the levels of preservatives in food and drinks. The 13-year-old children had the highest total daily intake on a body weight basis of benzoic acid among all age groups. A high daily consumption (95th percentile) of beverages contributed to 70% of the total intake. The contribution of benzoic acid for the high consumers from jam and preserved shrimps were 28% and 16% of the total intake, respectively (Bergsten, 2000).

In 1999, JECFA assessed the intake of benzoates from information provided by 9 countries (Australia, China, Finland, France, Japan, New Zealand, Spain, United Kingdom and USA) (JECFA, 1999). The food category that contributed most to benzoate intake was soft drinks. The best estimated intake was based on analyses involving either model diets or individual dietary records, and maximum limits specified by national governments or EU. The estimates of national mean intakes of benzoates were ranging from 0.18 mg/kg bw/day in Japan to 2.3 mg/kg bw/day in USA. The estimated benzoate intake by high consumers was reported to be 7.3 mg/kg bw/day in USA and 14 mg/kg bw/day in China.

A total diet study of sulphites, benzoates and sorbates was published in 2005 by FSANZ. In the Australian total diet study (ATDS), dietary exposure is estimated by determining the level of the substance in foods by laboratory analysis, and then combining this with the amount of food consumed, as determined in a separate study. Diets for each individual in the representative age-gender groups were derived for exposure estimations, based on a 24-hours recall from the 1995 National Nutrition Survey (NNS). Results were calculated for consumers only The mean estimated dietary exposure to benzoates was less than 2.5 mg/kg bw/day for all population groups assessed. The 95th percentile estimated dietary exposure was approximately 7 and 6 mg/kg bw/day for boys and girls aged 2-5 years, respectively. For children aged 2-5 years, the major contributing foods to benzoate exposure were cordial (sweet fruit flavoured drink), non-cola soft drinks and orange juice (FSANZ, 2005).

Soft drinks, 'saft' and nectar are the most important single source to the total daily intake of benzoic acid. A substantial change in the drinking patterns may also have a significant effect on the intake of benzoic acid.

9.6.2.5 *Exposure to benzene from soft drinks, 'saft' and nectar containing benzoic acid*

On a request from the Norwegian Food Safety Authority the manufacturers of soft drinks and 'saft' in Norway were asked to analyse the benzene content in soft drinks containing both sodium benzoate and ascorbic acid. Sixteen different soft drinks were analysed and 13 samples contained non-detectable levels of benzene. The 3 remaining samples contained benzene at levels between 0.7 and 4.7 μg/l.

9.6.3 Risk characterisation of benzoic acid and benzoate intake

9.6.3.1 *Benzoic acid and its salts*

The ADI of 0-5 mg/kg bw for benzoic acid and its salts, including benzyl alcohol and related benzyl derivatives used as flavourings, was allocated by SCF in 2002.

The estimated total intake of benzoic acid at the current level was above the ADI within the 95th percentile of 1-year-old children. For 2- and 4-year-old children, the benzoic acid intake within the 95th percentile was close to the ADI.

In the 100% scenario where all consumed soft drinks, 'saft' and nectar are assumed to contain intense sweeteners, children from 1- to 13-years will have an intake of benzoic acid within the 95th percentile exceeding the ADI with 4% to 18%, while the intake for adults were close to the ADI. The highest intake of 5.9 mg/kg bw/day in this scenario was estimated for the 1-year-old children. In humans and animals, benzoic acid and benzoates are absorbed, then conjugated with glycine and excreted in the urine as hippuric acid. This is a saturable reaction, and the glycine capacity might be exceeded during very high intakes of benzoic acid. Glycine is regarded as a non-essential amino acid, and temporary depletion in adults are not regarded as a problem. However, as stated by SCF, in rapidly growing organism such as children glycine might be regarded as a conditionally essential amino acid (SCF, 2002b) and depletion of glycine might be of concern as absence of glycine might lead to reduced weight gain. The capacity of glycine conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein.

The total benzoic acid exposure for children from all sources is not known. This risk assessment does not include exposure to benzoic acid from other sources like cosmetics or from flavourings in food such as benzyl alcohol and benzyl derivatives that are metabolised to benzoic acid in the human body. Adding the exposure to benzoic acid from other sources will even further increase the exceedances of the ADI. Therefore, the estimated high benzoic acid intake from food in 1- to 4-year-old children in Norway should be of special concern. VKM recommends that more detailed intake studies are performed where all sources of benzoic acid exposure are included.

9.6.3.2 *Benzene from soft drinks and 'saft'*

No safe exposure level has been recommended for benzene. However, the WHO guidelines for drinking-water quality have a guideline value for benzene in drinking water of 10 μg/l which may be associated with a 10^{-5} upper-bound excess lifetime cancer risk. In the European Council Directive 98/83/EC on the quality of water for human consumption, it was recommended that the benzene level should not exceed 1 μg/l. The risk assessment of benzene from soft drinks is limited to the analyses of only sixteen samples analysed in Norway.

One soft drink was found to have higher levels of benzene than recommended by EU, whereas two of the soft drinks contained benzene at a level of 1 μg/l and 0.7μg/l. The remaining soft drinks had benzene levels lower than the detection limit. None of the soft drinks contained levels of benzene that exceeded the level recommended by WHO for drinking water. VKM therefore concludes that the levels of benzene in soft drinks in Norway do not pose a safety problem.

9.7 Conclusions risk assessment of intense sweeteners and benzoic acid

The estimated intakes of the intense sweeteners aspartame, saccharin and cyclamate from soft drinks, 'saft' and nectar were well below ADI for all age groups both at the current level of intake and in the scenario where all soft drinks were assumed to contain intense sweeteners (100% scenario). It was not possible to estimate the intake of sucralose because sucralose first was introduced to the Norwegian market in 2005. At present use, it is anticipated that the intake of sucralose is well below ADI for all age groups. Altogether, no health concern is connected to the use of the above-mentioned intense sweeteners in soft drinks, 'saft' and nectar.

The estimated intake of acesulfame K among high consumers (95th percentile) of soft drinks, 'saft' and nectar in 1- year-old children at the current level was close to ADI, while the intake for the other age groups was well below ADI. A shift from sugar sweetened drinks to drinks with intense sweeteners increases the probability of exceeding ADI for acesulfame K within the high consumers among 1- and 2-year-old children. The intake of acesulfame K was below ADI for all other age groups after changing to soft drinks, 'saft' and nectar with intense sweeteners. The intake of acesulfame K from other food sources is not known, but could lead to an exceedance of ADI for 1-and-2-year old children. An exceedance of ADI would represent an erosion of the safety margin for acesulfame K exposure. It should be recognised that an effect level has not been observed, and thus no definitive NOAEL has been identified for acesulfame K. Thus, an ADI could in reality be higher than the one used in this risk assessment, resulting in an acceptable safety margin. VKM recommends that the intake of acesulfame K for young children should be closely monitored in the future.

At the current level, the estimated total intake of benzoic acid was close to ADI within the high consumers (95th percentile) of soft drinks, 'saft' and nectar of all age groups except men, and above ADI within the high consumers among 1-year-old children. Intake of benzoic acid from soft drinks, 'saft' and nectar was found to be the major single source of benzoic acid from food. When changing from sugar sweetened drinks to drinks with intense sweeteners, the total benzoic acid intake from food was above ADI within high consumers of all age groups except men. Children from 1- to 4-years of age were found to have the highest intake of benzoic acid on a body weight basis.

The calculated total benzoic acid intake from food does not include the intake of benzyl derivatives used as flavourings in food, and which are metabolised to benzoic acid in the body. In addition to the exposure from food, both adults and children might be exposed to a considerable amount of benzoic acid from cosmetics.

Adverse health effects of a high benzoic acid intake are anticipated to be of most concern for children. Benzoic acid is conjugated in the body with the amino acid glycine before excretion, and the glycine capacity might be exceeded during very high intakes of benzoic acid. This is mainly a concern for organisms during growth, such as children, where absence of glycine might lead to reduced weight gain. The capacity of glycine conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein. The total benzoic acid exposure to children from all sources is not known. Therefore, the estimated high benzoic acid intake from foods and drinks in 1- to 4-year-old children in Norway should be of special concern. VKM recommends that more detailed intake studies are performed where all sources of benzoic acid exposure are included.

10 Risk comparison

Soft drinks, 'saft' and nectar with sugar or intense sweeteners do not provide any valuable nutrients and are not an essential part of a diet. However, Norway has for a number of years been within the top 5 countries in the western world with respect to high consumption of soda (Norwegian Brewers and Soft Drink Producers, 2004). Furthermore, dietary surveys indicate that children and adolescents have a higher consumption of soft drinks and 'saft' than adults.

A high consumption of sugar and sugar sweetened soft drinks has been linked to health consequences such as overweight, diabetes type 2, and dental caries and dental erosion. A reduction in sugar intake by reducing the consumption of sugar sweetened soft drinks, 'saft' and nectar may result in health benefits such as reduced prevalence of overweight and diabetes type 2. Reduced consumption of sugar sweetened soft drinks, 'saft' and nectar may also result in an increased consumption of soft drinks and 'saft' with intense sweeteners, and thereby an increase in the total intake of intense sweeteners and benzoic acid.

In this report the health risks connected to both high consumption of sugar sweetened soft drinks, 'saft' and nectar and to soft drinks, 'saft' and nectar sweetened with intense sweeteners have been assessed. A comparison between these health risks has been made, especially with regard to vulnerable groups such as overweight/obese, diabetics and children.

10.1 Challenges in the risk comparison

Comparison of health risks represents a complicated undertaking. One challenge in the present risk comparison has been that different scientific approaches are used to estimate the health risks associated with the consumption of sugar/sugar sweetened soft drinks and the risks associated with the intake of intense sweeteners and benzoic acid. Moreover, it is almost impossible to judge the health effects of one food group such as sugar sweetened soft drinks, as it is most often the composition of the total diet, other lifestyle factors and genetic factors which are of importance for health outcomes.

In the risk assessment of e.g. intake of intense sweeteners, ADI values have been used as upper acceptable intake levels (see section 7.1.1). It has been discussed for several years whether the ADI concept is applicable to children, knowing that they often have a relatively higher intake of food and fluids compared to adults on a body weight basis. On the other hand, children have been found to have similar or higher elimination rates for xenobiotics compared to adults. Further, reproductive toxicology studies also cover young age groups. Thus, it is anticipated that ADI values also will cover children. If there is evidence that children are especially sensitive to a compound, this will have been taken into account when deriving the ADI. Since an uncertainty factor (of 100) is applied when deriving the ADI, an exceedance of ADI will not necessarily lead to immediate health effects, but it will reduce the safety margin.

In the risk evaluation of food consumption e.g. of soft drinks or sugar, an upper level of acceptable intake have not been established. The best evidence for a risk or benefit of food consumption is when results from observational epidemiological studies can be reproduced in randomised controlled studies, and when there is a plausible biological explanation. A health risk estimate of sugar sweetened soft drinks, 'saft' and nectar would have to be based on a summary of the consistency, strength and quality of the individual studies.

Sugar sweetened soft drinks, 'saft' and nectar are the most important single source of added sugar among children and adolescents. The health risk from consumption of sugar sweetened soft drinks, 'saft' and nectar may be evaluated by comparing the energy percentage derived from added sugar with the Nordic Nutrition Recommendations on added sugar (maximum 10% of the energy should be derived from added sugar).

10.2 Methodological considerations

10.2.1 Consumption of soft drinks, 'saft' and nectar

The consumption data of soft drinks, 'saft' and nectar used in the present report are based on national representative dietary surveys conducted in the period 1997-2001. The largest time span between the time of the surveys and today is for the Norkost study (9 years). Due to this time span, the consumption data are not fully representative for today's consumption. The new figures from Canadean Ltd. (Chapter 5) for carbonated soft drinks indicate that there has not been a large change in the total consumption of carbonated soft drinks from 2002-2006, but the proportion of sugar sweetened carbonated soft drinks versus soft drinks with intense sweeteners seems to have changed. There has been an increase in the proportion of carbonated soft drinks with intense sweeteners and a reduction in the proportion of sugar sweetened carbonated soft drinks. Thus, the figures for consumption of sugar sweetened soft drinks in the present report may be a small overreporting of today's situation and there may be a small underreporting of soft drinks with intense sweeteners. The new figures from Canadean Ltd. do not indicate in which age groups the changes have occurred. Moreover, the consumption data and concentration data from the industry do not relate to the same time period and only partly relate to the same products. New dietary surveys including brand-names are necessary in order to conduct an up to date risk assessment of high intakes of sugar, intense sweeteners and benzoic acid.

Another issue related to the total consumption of soft drinks is the introduction of new products on the market since 2001, and which per definition should be included in the category of soft drinks, e.g. water sweetened with sugars or intense sweeteners. There are no data about the impact of these new products on the total consumption, or if these products have replaced some of the "old" soft drinks.

The dietary data on consumption of added sugar and soft drinks, 'saft' and nectar used in the present report are relatively valid for the mean consumption. The precoded food diary used in the survey among 9-year-old children showed that there was no systematic misreporting of unhealthy food. In general, consumption data at the 95th percentile will often be less accurate than the mean value because they reflect a smaller sample size. The over- and underreporting of energy intake identified among young children (1- and 2-year-olds) and among 9- and 13-year-olds, respectively, may have an impact on the validity of the 95th percentile. The size of this problem is not quantified. In some other countries the 97.5th percentile is used as background for risk estimates. Using the 95th percentile will reduce the effect of a problem related to over-reporting, and increase the sample size of the high consumers. This will reduce the uncertainties in the intake estimates for this group compared to the 97.5th percentile.

10.2.2 Intake of intense sweeteners and benzoic acid

Intake data on intense sweeteners from other sources than soft drinks, 'saft' and nectar are not available for children. Therefore, the total intake of the intense sweeteners cannot be estimated for this group. This may be a challenge when undertaking a risk assessment, especially for intense sweeteners such as acesulfame K where the margin between the intake among high consumers of children (95th percentile) from soft drinks, 'saft' and nectar and the ADI is small. Although it was reported in 1998 that the intake from soft drinks, 'saft' and nectar contributed to more that 50% of the intake of acesulfame K among adults and also was the main contributor to the intake of aspartame (Bergsten, 1998), the contribution from other food items cannot be neglected. No

previous intake estimates for acesulfame K and aspartame have been performed in children, and it is therefore not possible to predict the relative contribution from soft drinks, 'saft' and nectar compared to other sources. The main contributor to the intake of cyclamate and saccharin was in 1998 found to be table top sweeteners (Bergsten, 1998). The intake from table top sweeteners is not included in the present intake estimates.

Sucralose was introduced to the Norwegian market as late as 2005, and no intake estimates are yet available. Intake estimates from other countries where sucralose has been used for several years are used in the risk assessment of sucralose in the present report. However, dietary habits are different between countries and a comparison with intakes in other countries should be done with precaution.

For benzoic acid and its salts, total intake estimates from food for all age groups are available. However, the intake estimates do not include compounds that are metabolised to benzoic acid in the body or intake from other sources than food. Benzyl derivatives are added to food as flavouring compounds and are metabolised to benzoic acid in the body. In addition, a relatively large amount of benzoic acid is used in cosmetic, which will add considerably to the total exposure to benzoic acid.

10.3 Risks associated with high consumption of sugar sweetened soft drinks, 'saft' and nectar at the current level

During the last five years there has been an intense discussion both in the media, in the beverage industry and in the relevant research areas about the health consequences of a high consumption of added sugar and sugar sweetened drinks. Especially the association between high consumption of sugar sweetened beverages and risk of weight gain and obesity has been in focus, partly because of the obesity epidemic experienced in most countries worldwide.

10.3.1 Percentage of energy (E%) from added sugar

On average the percentage of energy deriving from added sugar is high among Norwegian children and adolescents. Sugar sweetened soft drinks, 'saft' and nectar are the most important sources of added sugar. The mean energy percentage from added sugar was found to be 9-10E% for adults and 12E%, 15E%, 17E% and 19E% for 2-, 4-, 9- and 13-year-olds, respectively. Among the 4-, 9- and 13-year-olds about 85% had more energy from added sugar than the recommended maximum level of 10E%. Among the 1- and 2-year-olds the proportions were 43% and 56%, respectively. About 40% of the added sugar in the diet of the 2-, 9- and 13-year-olds came from sugar sweetened soft drinks (soda and 'saft') (see Table 7).

10.3.2 Results from epidemiological studies

Available epidemiological literature supports a positive link between sugar sweetened drinks and the risk of overweight and obesity, even if the interpretation of the published studies is complicated by several method-related issues.

The WHO report "Diet, Nutrition and the Prevention of Chronic Disease" from 2003 summarised that there probably is a positive association between high consumption of sugar sweetened soft drinks and risk of weight gain and obesity (WHO, 2003). The WHO conclusion was based on a limited number of studies, but the body of scientific evidence supporting a positive association between sugar sweetened soft drinks and overweight/obesity has increased since 2003.

In addition to a potential role in weight gain, the consumption of sugar sweetened soft drinks has been suggested to increase the risk of type 2 diabetes. Further research is needed to decide whether sugar sweetened soft drinks initiate development of type 2 diabetes as such or through its effect on body weight.

For decades there has been consensus in the scientific literature about the role of sugars in the development of dental caries. The association between sugar intake and dental caries is well documented and relatively linear. Individuals with good oral hygiene and regular fluoride exposure may tolerate higher levels of sugar intake before caries occurs. Sugar sweetened drinks also affect incidence of dental erosion caused by their low pH. The pH range in the most sold sugar sweetened soft drinks in Norway shows that all of them have a pH far below the critical pH for dissolution of the hard tissues of the teeth (Table 5).

10.3.3 Conclusions risks associated with high consumption of sugar sweetened soft drinks, 'saft' and nectar at the current level

The consumption of sugar sweetened soft drinks is linked to important health concerns such as overweight, obesity and diabetes type 2 in addition to concerns such as dental disease. Moreover, these drinks provide no valuable nutrients apart from fluids. In conclusion, there seems to be much to gain by reducing consumption of sugar sweetened soft drinks.

10.4 Risks associated with high consumption of soft drinks, 'saft' and nectar with intense sweeteners at the current level

In recent years, with more focus on weight and the negative health effects of a high intake of sugar, the use of intense sweeteners has increased. A new intense sweetener (sucralose) has also been introduced to the Norwegian market. In 2006, 35% of the Norwegian population expressed that they are concerned about the intake of food additives (Markeds- og Mediainstituttet, 2006).

10.4.1 Dental health

Intense sweeteners cannot be fermented by bacteria in the mouth and do not produce acids that erode tooth enamel. Intense sweeteners per se do not cause dental decay.

The pH range in the most sold soft drinks, 'saft' and nectar with intense sweeteners in Norway shows that all of them have a pH far below the critical pH for dissolution of the hard tissues of the teeth (Table 5). The erosive potential is therefore the same for sugar sweetened drinks and drinks with intense sweeteners.

10.4.2 Intake of intense sweeteners and benzoic acid

Bergsten (1998) reported that artificial sweetened drinks are the most important sources for the intake of intense sweeteners among adults, except for saccharin and cyclamate. However, the estimated consumption of soft drinks, 'saft' and nectar at the current level in the present report, showed intakes of aspartame, saccharin and cyclamate that were well below ADI.

Saccharin and cyclamate are used in very few brands of soft drinks, 'saft' and nectar, and intake estimates for most age groups were zero or close to zero. The major source for the intake of saccharin and cyclamate for adults was previously found to be table top sweeteners (Bergsten, 1998). A pilot survey among 1- to 19-year-old children with diabetes in Norway showed that the estimated intake of cyclamate within the 90th percentile was 7.7 mg/kg bw/day and thus above the ADI for cyclamate of 0-7 mg/kg bw (Drøpping, 2003). The total intake, including table top sweeteners, has not been estimated, and it is not possible to predict whether groups such as diabetic children can be at risk of having an intake above ADI at current use levels. In a recent review of the European intake of sweeteners, it was concluded that one population group, children with diabetes, were close to, or slightly above, the ADI for cyclamate although reliable intake data for this sub-group were noted as being limited (Renwick, 2006).

For the high consumers (95th percentile) in all age groups the intake of aspartame was well below the ADI of 0-40 mg/kg bw. The highest intake of aspartame was found for 1- and 2-year-old children and were estimated to 8.2 and 8.3 mg/kg bw, respectively. Although the total intake

of aspartame has not been estimated, it is likely that soft drinks, 'saft' and nectar are the major sources. Intake from other sources will probably not increase the current intake to a level above ADI, even for children.

The group that has the highest estimated intake of acesulfame K at the current level is 1-year-old children. The high consumers (95th percentile) among this group had an estimated acesulfame K intake of 6.5 mg/kg bw/day, which is 72% of the ADI for acesulfame K of 0-9 mg/kg bw. As for the other sweeteners, the total intake of acesulfame K in this group is not known. Even though a large part of the acesulfame K intake comes from soft drinks, 'saft' and nectar, the contribution from other sources cannot be neglected. An intake study among adults in Norway in 1998 showed that the acesulfame K intake from sources such as sweets, jam and "chocolate milk/ drink" contributed to about 13% of the ADI (Bergsten, 1998). It cannot be excluded that high consumers among children may have a current intake that will exceed the ADI for acesulfame K. Intake levels close to ADI from soft drinks and squashes within the 95th percentile among children was also reported in a Dutch study from 2004 (van Rooij-van den Bos *et al*., 2004). In a recent Position Statement from the American Dietetic Association (2004), the intake of acesulfame K among children (60% of ADI) was noted as an issue to be monitored further, to gain more data on intake for future assessments.

The total intake of benzoic acid and its salts was available for all age groups. In all groups, except men, the intake among high consumers at the current estimated level was above 4 mg/kg bw/day. For 1-year-old children the intake among high consumers was 5.5 mg/kg bw/day, which is higher than the ADI (0-5 mg/kg bw) for benzoic acid. Although intake of benzoic acid and its salts from other foods than soft drinks, 'saft' and nectar was included in the estimates, other sources of exposure also exist for benzoic acid. Benzyl derivatives used as flavours in food are metabolised to benzoic acid in the body. The former SCF stated that exposure to benzyl derivatives from food also should be included in the derivation of ADI for benzoic acid. However, the exposure from benzyl derivatives in food was not known. In addition, it might be expected that a considerable exposure of benzoic acid may come from the use of cosmetic products. Benzoic acid and benzoates can be used in a wide range of cosmetic products, such as oral care products (toothpaste etc.) and leave on products (creams, lotions etc.), which are products also relevant for children's exposure to benzoic acid. The exposure to benzoic acid from cosmetic products can be relatively high and the estimated systemic exposure dose (SED) of benzoic acid from cosmetics were estimated to be 2.43 mg/kg bw/day for adults by the Scientific Committee on Consumer Products in 2005 (SCCP, 2005). It should be noted that the SED was calculated from a 100% absorption of benzoic acid through the skin, since reliable studies on the dermal absorption of benzoic acid were lacking (SCCP, 2005). The dermal absorption of benzoic acid is not likely to be as high as 100%, so the calculated SED of 2.43 mg/kg bw/day from cosmetics is therefore clearly a worst-case estimate.

10.4.3 Possible adverse health effects – discussion

The literature on intense sweeteners and diabetes, and possible effects on insulin production are limited. Intense sweeteners have not been shown to raise plasma insulin, and the scarce literature data indicate that intense sweeteners do not affect insulin production.

No adverse health effects are anticipated to be connected with the intake of aspartame, saccharin and cyclamate from soft drinks, 'saft' and nectar at the current level, since the levels of intake were well below ADI. No intake estimates for sucralose from Norway exist. However, it is anticipated that the current intake will not lead to any negative health effects since there for the time being are few products with sucralose on the market in Norway.

The intake of acesulfame K from soft drinks, 'saft' and nectar at the current level is approaching the ADI among children. The contribution of other food sources to the total exposure to acesulfame K is not known, but could lead to an exceedance of the ADI for these age groups. This would represent an erosion of the safety margin for acesulfame K exposure. Children are regarded as a sensitive

group because they have a relative higher consumption of food and drinks compared to adults on a body weight basis. It should be recognised that an effect level has not been observed, and thus no definitive NOAEL has been identified for acesulfame K. Thus, an ADI could in reality be higher than the one used in this risk assessment, resulting in an acceptable safety margin. Acesulfame K exposure from other sources than food is not likely. VKM recommends that the intake of acesulfame K in young children should be closely monitored in the future.

The benzoic acid intake from soft drinks, 'saft' and nectar at the currant level exceeded ADI for high consumers among 1-year-old children. In humans and animals, benzoic acid and benzoates are absorbed, conjugated to glycine and excreted in the urine as hippuric acid. This is a saturable process, which means that the glycine capacity can be exceeded after high intakes of benzoic acid. In animal experiments it was found that the toxic effects of benzoic acid and benzoates appeared when glycine no longer was available. Benzoic acid and benzoates were found to affect birth weight, postnatal growth and survival in rats (SCF, 2002b). Glycine is regarded as a non-essential amino acid, and temporary depletion in adults is not regarded as a problem. However, as stated by SCF, in rapidly growing organisms such as children, glycine might be regarded as a conditionally essential amino acid (SCF, 2002b) and limited availability of glycine in children might lead to reduced weight gain. The capacity of glycine conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein. The total benzoic acid exposure in children, including benzyl derivates and cosmetics is not known. Therefore, the estimated high benzoic acid intake from food in 1- to 4-year-old children in Norway should be of special concern. The Norwegian Food Safety Authority does not recommend giving products containing sweeteners, preservatives and colours to 1- to 3-year-old children. VKM recommends that more detailed intake studies should be performed where all sources of benzoic acid exposure are included.

10.4.4 Conclusion risks associated with high consumption of soft drinks, 'saft' and nectar with intense sweeteners at the current level

In the current situation the acesulfame K intake from soft drinks, 'saft' and nectar among 1-year-old children approaches the ADI. The intake of acesulfame K from other sources is not known for this group, but might affect considerably the total intake. It cannot be excluded that high consumers among young children can reach a total intake that exceeds ADI for acesulfame K, and it is therefore recommended that the intake of acesulfame K in Norwegian children is supervised. This is in line with a statement from the American Dietetic Association where it was suggested that especially the intake of acesulfame K in children is noted as an issue to be monitored further.

The intake of aspartame, cyclamate and saccharin from soft drinks, 'saft' and nectar at the current level are well below ADI in all age groups.

The estimated total benzoic intake at the current level is close to ADI in all age groups except men, and above ADI for 1-year-old children. Although the total intake of benzoic acid from food is known for all age groups the exposure from other sources, such as benzyl derivates in food and benzoic acid from cosmetics is still not known. It is assumed that adults and children in addition are exposed to a considerable amount of benzoic acid from cosmetics, which will contribute to an exceedance of ADI. VKM therefore recommends that more detailed intake studies should be performed in which all sources of benzoic acid exposure is included.

10.5 Consequences of changing from sugar sweetened soft drinks to soft drinks, 'saft' and nectar to drinks with intense sweeteners

Soft drinks sweetened with either sugar or intense sweeteners do not contribute with any valuable nutrients apart from fluids. In a public health related effort to reduce the consumption of sugar sweetened soft drinks one should promote consumption of other beverages such as water, low-fat milk and small quantities of fruit juices. However, a strategy to replace all consump-

tion of sugar sweetened soft drinks with water or milk may be an unrealistic suggestion. VKM considers that the consumer would probably more easily change from consumption of sugar sweetened soft drinks to consumption of similar tasting beverages such as soft drinks with intense sweetener, totally or partly.

10.5.1 Results from epidemiological studies

The majority of the epidemiological studies conducted on the association between consumption of beverages with intense sweeteners and weight regulation indicate that intense sweeteners do not lead to an increase in the energy intake or body weight. It seems as if consumption of soft drinks with intense sweeteners may contribute to a reduction of weight if they replace sugar sweetened soft drinks (Raben *et al*., 2002). If intense sweeteners, as sugar-replacements, can contribute to weight reduction and improved insulin sensitivity, it is also possible that they may reduce the risk of type 2 diabetes. It is important to point out that the number of studies in this area is limited and most studies are short-term. The potential long-term effects are not known.

10.5.2 Percentage of energy from added sugar in the different scenarios

In the scenario, where 50% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners and the other half contains added sugar (50% scenario), the estimated mean and median percentage of energy from added sugar is below or close to 10E% among both 1- and 2-year-olds and adults. However, 76-84% of the older children (4-13 years of age) still have a percentage of energy from added sugar higher than 10E%.

In the scenario where 100% of the consumed soft drinks, 'saft' and nectar contain intense sweeteners (100% scenario), the mean and median percentages of energy from added sugar are estimated to be below or close to 10E% for all age groups. About 50% of the children aged 4- to 13 years still have an estimated energy percentage from added sugar higher than 10E%, while the proportions are 25% and 17% among 1- and 2-year-olds, respectively. So, even in the 100% scenario a large proportion of the children aged 4- to13 years will have a higher energy percentage from added sugar than recommended.

Moving from the current situation to the 50% scenario has some impact on the mean intake of added sugar, and on the proportion of consumers having an energy percentage from added sugar higher than 10E%. In contrast, moving from the current situation to the 100% scenario will have a very large impact on the energy percentage from added sugar, especially for the age groups of 2, 4, 9 and 13 years. The estimated mean energy percentage from added sugar in the 100% scenario will be below or close to the recommended maximum level of 10E% in all the population groups. This is illustrated in Figures 8-14, where it can be seen that the curves for the 100% scenario are narrowing and moving towards the left in relation to the other two curves (current situation and 50% scenario) for all age groups, but especially for the age groups 2, 4, 9 and 13 years. The large effect of the 100% scenario in these age groups may be explained by the high contribution of added sugar from sugar sweetened soft drinks and 'saft' (Table 7). This means that independent of the energy percentages from added sugar that are selected as cut-offs in support of a health risk, a smaller proportion will have values higher than the cut-offs in the 100% scenario.

10.5.3 Intake of intense sweeteners in the different scenarios

The intake estimates for all the intense sweeteners are well below ADI in the 50% scenario. In the 100% scenario, the intake estimates for the high consumers of aspartame, saccharin and cyclamate are well below ADI. Changing from the current level to the 50% scenario or the 100% scenario has no effect on the intake of saccharin or cyclamate, since these intense sweeteners are only used in very few brands of soft drinks, 'saft' and nectar.

The aspartame and acesulfame K intakes among high consumers were lower in the 50% scenario than at the current estimated level of intake, especially for 1-and 2-year-old children. This shows that more than 50% of soft drinks, 'saft' and nectar contain intense sweeteners at the current

level of intake among the high consumers of 1-and 2-year-old children, leading to a reduction in the intake of intense sweeteners in the 50% scenario.

The intake of aspartame increased slightly when changing from the current level to the 100% scenario for all age groups, except 1-year-old children. However, the intake level of aspartame is still far from reaching the level of ADI in the 100% scenario, and is therefore of no concern.

When changing the intake from the current level to the 100% scenario, a considerable increase was observed in the intake of acesulfame K among high consumers of soft drinks, 'saft' and nectar within the group of 1- and 2-year-old children. High consumers among 1- and 2-year-old children in the 100% scenario had intakes of 6.4 and 7.1 mg/kg bw/day, respectively, indicating that young children may possibly reach ADI when acesulfame K intake from other sources than soft drinks, 'saft' and nectar is included. For all other age groups the intake of acesulfame K is well below ADI even at the 95th percentile. Although sweeteners and preservatives in general are not authorised for use in food products specially intended for young children (1- to 3-years-old), young children were found to have the highest intake of acesulfame K. It cannot be excluded that 1- to 3-year-old children may obtain an intake at or above ADI when intake from additional sources is included. Also for the remaining age groups a higher intake of acesulfame K was found in the 100% scenario, although for these groups the intake was still well below ADI.

10.5.4 Intake of benzoic acid in the different scenarios

The estimated total intake of benzoic acid in the 50% scenario shows that high consumers (95th percentile) among 1- and 2-year-old children are above or at ADI, while the high consumers within the age groups 4- to13 years and women have intakes close to the ADI for benzoic acid.

High consumers in all age groups, except 4-year-old children, have increased intake of benzoic acid when comparing the current intake level with the intake in the 50% scenario. The increase results in an intake above ADI for 2-year-old children in addition to 1-year-old children who have an intake above ADI also at the current intake level.

The estimated benzoic acid intake in the 100% scenario shows that the high consumers within all groups of 1- to 13-year-old children have an estimated intake above ADI, ranging from 5.9 mg/kg bw for 1-year-old children to 5.2 mg/kg bw/day for 2- and 4-year-old children. The high consumers among women have an estimated intake at ADI. Men with a high consumption were estimated to have an intake of 4.2 mg/kg bw (95th percentile), and were still below ADI.

The weighted average content of benzoic acid was slightly higher in soft drinks, 'saft' and nectar with intense sweeteners than in sugar sweetened drinks. An increase in intake of benzoic acid was therefore observed for the high consumers of soft drinks, 'saft' and nectar when changing from the current intake level to the 100% scenario, where all age groups except men have an intake above ADI.

10.5.5 Conclusion changing from sugar sweetened soft drinks, 'saft' and nectar to drinks with intense sweeteners

Changing from the current level to the 100% scenario has a large impact on the percentage of energy from added sugar especially for the age groups of 2, 4, 9 and 13 years. The mean and median percentages of energy from added sugar were estimated to be below or close to 10E% for all age groups in the 100% scenario.

Changing from the current level to the 100% scenario resulted in an increase in the intake among high consumers for both acesulfame K and benzoic acid. The intake of acesulfame K from soft drinks, 'saft' and nectar approached the ADI among 1- and 2-year-old children, while the total intake for high consumers of all groups except men exceeded ADI for benzoic acid. Children aged 1- to 4 years were found to have the highest estimated intakes of benzoic acid in the 100% scenario.

11 Conclusions

When concluding, it is important to be aware of the limitations in the present risk assessment. The consumption data from the dietary surveys used in this report have their limitations due to methodological aspects such as under- and-overreporting. The dietary surveys used in the exposure assessments have not collected data at brand-name level. They are conducted between 1997 and 2001, and may therefore not be fully representative for the current situation. In addition, no data on the intake of intense sweeteners from other sources than soft drinks, 'saft' and nectar are available for children.

The epidemiological data generating the background for the conclusions on health effects (overweight and diabetes) from soft drinks all have their limitations including methodological aspects such as small sample sizes, short duration of follow-up, lack of repeated measures in dietary exposures and outcomes, and confounding by other dietary and lifestyle related factors. These limitations are discussed throughout the report. More studies on the association between soft drink consumption and overweight and diabetes are needed to confirm the conclusions. Especially research related to the consumption of sugar sweetened soft drinks and diabetes, both type 1 and type 2 is scarce.

Epidemiological and experimental evidence indicate that a high consumption of sugar sweetened beverages is associated with weight gain and obesity. Further, the majority of studies done on the relationship between intake of intense sweeteners and body weight indicate that intense sweeteners do not lead to an increase in the energy intake and body weight. Although more data and research are needed, sufficient evidence exists to discourage consumption of sugared drinks as part of a healthy diet.

A change in consumption pattern from sugar sweetened soft drinks to soft drinks with intense sweeteners may reduce the risk of weight gain associated with consumption of soft drinks. If a shift from sugar sweetened drinks to drinks with intense sweeteners reduces risk of overweight, it may also have a positive effect on the risk of developing diabetes type 2.

The association between sugar intake and dental caries is well documented and relatively linear. In individuals with good oral hygiene and regular fluoride exposure, higher levels of sugar intake may be tolerated before caries occurs. As shown in Table 7, consumption of sugar sweetened soft drinks is the most important single source of the total consumption of added sugar among children and adolescents. Comparing mean daily intake of total added sugar in the current situation (Table 8) and in the 50% scenario (Table 10) will give a reduction in added sugar between 14-20% among children and adolescents (2- to 13-year-olds).

Replacing added sugar in all soft drinks, 'saft' and nectar with intense sweeteners (100% scenario) (Table 12) will give a reduction in intake of added sugar between 37-46% among children and adolescents (2- to 13-year-olds). A shift from sugar sweetened soft drinks to soft drinks with intense sweeteners will most probably reduce the incidence of caries. There is no difference in pH and acid concentrations between sugar sweetened soft drinks and soft drinks with intense sweeteners. Thus, a reduction in sugar content will not affect the incidence of dental erosion.

Moving from the current situation to the scenario where 50% of all soft drinks, 'saft' and nectar were assumed to contain intense sweeteners has some impact on the mean intake of added sugar and on the proportion of the population having a percentage of energy from added

sugar higher than 10E%. In contrast, moving from the current situation to the scenario where 100% of all soft drinks, 'saft' and nectar were assumed to contain intense sweeteners (100% scenario) will have a very large impact on the energy percentage from added sugar, especially for the age groups of 2, 4, 9 and 13 years. The estimated mean percentages of energy from added sugar in the 100% scenario will be below or close to the recommended maximum level of 10E% in all the population groups.

The estimated intakes of aspartame, saccharin and cyclamate from soft drinks, 'saft' and nectar were well below ADI for all age groups both at the current level of intake and in the 100% scenario. It was not possible to estimate the intake of sucralose because sucralose first was introduced to the Norwegian market in 2005. At the present use, it is anticipated that the intake of sucralose is well below ADI for all age groups. Altogether, no health concern is connected to the use of the above-mentioned sweeteners in soft drinks, 'saft' and nectar.

There were no reported use of the intense sweeteners neohesperidin DC and thaumatin in soft drinks, 'saft' and nectar, and therefore no risk assessments were performed for these sweeteners.

At the current level, the estimated intake of acesulfame K among high consumers of soft drinks, 'saft' and nectar in 1-year-old children was close to ADI. The intake of acesulfame K from other foods than soft drinks, 'saft' and nectar is not known, but might contribute to an exceedance of ADI in this age group. For the other age groups the intake at the current level was well below ADI.

The estimated acesulfame K intake among high consumers was lower in the 50% scenario than at the current level of intake, especially among 1- and 2-year-old children. In the 100% scenario, the acesulfame K intake among high consumers was estimated to approach the ADI in 1- and 2-year-old children. The contribution from other sources to the total exposure to acesulfame K is not known, but could lead to an exceedance of the ADI in 1- and 2-year-old children. This would represent an erosion of the safety margin for acesulfame K exposure. It should be recognised that an effect level has not been observed, and thus no definitive NOAEL has been identified for acesulfame K. Thus, an ADI could in reality be higher than the one used in this risk assessment, resulting in an acceptable safety margin. High consumers among the other age groups would still be below the ADI for acesulfame K if changing to the 100% scenario.

At the current level, the estimated total intake of benzoic acid was close to the ADI among high consumers of soft drinks, 'saft' and nectar in all age groups except men, and above the ADI among high consumers for 1-year-old children. Soft drinks, 'saft' and nectar were found to be the major single source to benzoic acid exposure from food. The current benzoic acid intake from food does not include the intake of benzyl derivatives used as flavourings in food, and which are metabolised to benzoic acid in the body. In addition to the exposure from food, both adults and children might be exposed to a considerable amount of benzoic acid from cosmetics.

The estimated total benzoic acid intake increased for all age groups except 4-year-old children when changing to the 50% scenario. High consumers among both 1- and 2-year-old children reached or exceeded ADI for benzoic acid in the 50% scenario. Changing from the current situation to the 100% scenario resulted in a total benzoic acid intake above ADI among high consumers in all age groups except men. Children, from 1- to 4-years of age, were found to have the highest estimated intake of benzoic acid relative to their body weight. Any contribution from benzyl derivatives and cosmetics will add to this exceedance.

Adverse health effects of a high benzoic acid intake are anticipated to be of most concern for

children. Benzoic acid is conjugated in the body with the amino acid glycine before excretion, and the glycine capacity might be exceeded during very high intakes of benzoic acid. This is mainly a concern for organisms during growth, such as children, where absence or limited availability of glycine might lead to reduced weight gain. The capacity of glycine conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein. The total benzoic acid exposure in children from all sources is not known. Therefore, the estimated high benzoic acid intake in 1- to 4-year-old children in Norway should be of special concern.

12 Recommendations

The Norwegian Scientific Committee for Food Safety recommends:

- More up-to-date and detailed dietary surveys, including information on brand-names should be performed in Norway for different age/population groups.

- More research on the association between added sugar and health is needed, especially regarding diabetes type 2.

- The estimated intake of acesulfame K approached ADI for young children and the contribution from other food sources than soft drinks, 'saft' and nectar is not known. VKM recommends that the intake of acesulfame K for young children should be closely monitored in the future.

- The children from 1- to 4-years of age were found to have the highest estimated intakes of benzoic acid relative to their body weight, and their intakes exceeded the ADI. The contribution from benzyl derivates used as flavourings in food and which are metabolised to benzoic acid in the body or exposure to benzoic acid from cosmetics have not been included in the estimates. VKM recommends that more detailed intake studies are performed where all sources of benzoic acid exposure are included.

13 Answers to the terms of reference

The impact on health from sugar intake through soft drinks, 'saft' and nectar focusing mainly on overweight and diabetes.

Five out of 9 prospective studies and 4 out of 4 intervention studies showed a positive association between high consumption of sugar sweetened soft drinks and weight gain/obesity. In conclusion, epidemiological and experimental evidence indicate that a higher consumption of sugar sweetened soft drinks is associated with weight gain and obesity.

There are few studies on the association between consumption of sugar sweetened beverages and risk of developing diabetes, especially diabetes type 1. The few prospective studies available indicate a positive correlation between sugar sweetened beverage consumption and the risk of developing diabetes type 2. However, this may result from the increased risk of weight gain and obesity observed with a high consumption of sugar sweetened beverages, and may not necessarily be a direct effect of the sugar sweetened beverages.

The impact on consumer health if 50% of the consumption of soft drinks, 'saft' and nectar contain intense sweeteners and 50% contain sugar, including:
Do intense sweeteners affect the production of insulin in the body, and how will this affect the consumer?

The literature on intense sweeteners and diabetes, and possible effects on insulin production are limited. Intense sweeteners have not been shown to raise plasma insulin, and the scarce literature data indicate that intense sweeteners do not affect insulin production.

The impact on consumer health if 50% of the consumption of soft drinks, 'saft' and nectar contain intense sweeteners and 50% contain sugar, including:
What will the effect be on the total intake of intense sweeteners and the preservative benzoic acid if intense sweeteners replace sugar in all soft drinks, 'saft' and nectar?

If intense sweeteners replace sugar in 50% of all soft drinks, 'saft' and nectar, the mean and median energy percentage deriving from added sugar will be below or close to 10E% in both 1- and 2-year-old children and adults. Still, 76-84% of the older children (4- to 13 years of age) will have a percentage of energy from added sugar higher than 10E%.

The intake estimates for aspartame, acesulfame K, saccharin and cyclamate from soft drinks, 'saft' and nectar in all age groups are well below ADI in the 50% scenario. The intakes of these sweeteners are not considered to be of any public health risk. Exposure from other sources than soft drinks, 'saft' and nectar for children is not included in the intake estimates.

In the 50% scenario, the estimated total intake of benzoic acid was close to ADI among high consumers of the age groups 4- to 13 years and women, and above ADI among 1- and 2-year-old children. Benzoic acid is conjugated in the body with the amino acid glycine before excretion, and the glycine capacity might be exceeded during very high intakes of benzoic acid. This is mainly a concern for organisms during growth, such as children.

The impact on consumer health if 50% of the consumption of soft drinks, 'saft' and nectar contain intense sweeteners and 50% contain sugar, including:
How will dental health be affected if intense sweeteners replace the sugar in 50% of all soft drinks, 'saft' and nectar?

There is a relatively linear relationship between sugar intake and prevalence of dental caries, while intense sweeteners per se do not cause caries. Comparing mean daily intake of total added sugar in the current situation and in the 50% scenario will give a reduction in added sugar between 14-20% among children and adolescents (2- to 13-year-olds).

Depending on the consumption frequency of soft drinks, 'saft' and nectar with added sugar, oral hygiene and fluoride exposure, a slight reduction in caries prevalence is expected. A higher reduction in caries prevalence is expected among adolescents compared to adults.

The erosive potential is the same for sugar sweetened soft drinks, 'saft' and nectar and drinks with intense sweeteners. Thus, a reduction in the intake of added sugar in the 50% scenario will not affect the prevalence of dental erosion.

The impact on consumer health if all soft drinks, 'saft' and nectar contain intense sweeteners instead of sugar, including:
What will the effect be on the total intake of intense sweeteners and the preservative benzoic acid if intense sweeteners replace sugar in all soft drinks, 'saft' and nectar?

A replacement of sugar in 100% of all soft drinks, 'saft' and nectar with intense sweeteners (the 100% scenario), will have a very large impact on the percentage of energy from added sugar. The mean and median energy percentage from added sugar will be below or close to 10E% for all age groups. About 50% of the children aged 4- to 13 years will still have an estimated percentage of energy from added sugar higher than 10E%, while these proportions will be 25% and 17% among 1- and 2-year-olds, respectively.

The estimated intake of aspartame, cyclamate and saccharin from soft drinks, 'saft' and nectar in the 100% scenario will still be well below ADI for all age groups for the respective sweetener, and are not considered to represent any public health risk. The acesulfame K intake for high consumers of soft drinks, 'saft' and nectar is estimated to approach the ADI among 1- and 2-year-old children. The contribution from other sources to the total exposure to acesulfame K is not known, but could lead to an exceedance of the ADI for this age group. This would represent an erosion of the safety margin for acesulfame K exposure. It should be recognised that an effect level has not been observed, and thus no definitive NOAEL has been identified for acesulfame K. Thus, an ADI could in reality be higher than the one used in this risk assessment, resulting in an acceptable safety margin. High consumers among the other age groups would still be below the ADI for acesulfame K if changing to the 100% scenario.

The total benzoic acid intake from food in the 100% scenario will be above ADI for high consumers in all age groups except men. High consumers among children from 1- to 4-years of age were found to have the highest intake. Benzoic acid is conjugated in the body with the amino acid glycine before excretion, and the glycine capacity might be exceeded during very high intakes of benzoic acid. This is mainly a concern for organisms in growth, such as children, where absence of glycine might lead to reduced weight gain. The capacity of glycin conjugation in children is not known. It is likely to be dependent on the nutritional status and intake of glycine. On average, Norwegian children have a sufficient intake of protein. The total benzoic acid exposure to children is not known, and the estimated high intake of benzoic acid from foods and drinks in 1- to 4-year-old children in Norway should therefore be of special concern.

The impact on consumer health if all soft drinks, 'saft' and nectar contain intense sweeteners instead of sugar, including:

How will dental health be affected if intense sweeteners replace sugar in all soft drinks, 'saft' and nectar?

Comparing mean daily intake of total added sugar in the current situation and in the 100% scenario will give a reduction in added sugar between 37-46% among children and adolescents (2- to 13-year-olds).

Depending on the consumption frequency of soft drinks, 'saft' and nectar with added sugar, oral hygiene and fluoride exposure, a reduction in caries prevalence will most probably occur. A higher reduction in caries prevalence is expected among adolescents compared to adults.

The erosive potential is the same for sugar sweetened soft drinks, 'saft' and nectar and drinks with intense sweeteners. Thus, a reduction in intake of added sugar in the 100% scenario will not affect the prevalence of dental erosion.

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ANNEXES

ANNEX 1

EXAMPLE ON CALCULATION OF WEIGHTED AVERAGE CONTENT OF A SUBSTANCE

The weighted average values for soft drinks, 'saft' and nectar are calculated based on information on actual content of food additives and sugar and sales volumes provided by the food manufacturers.

Product	Substance X	Sales figure	Substance X * Sales figure
A	12	3 000	36 000
B	42	200 000	8 400 000
C	37	500	18 500
Sum		203 500	8 454 500
Weighted average content	41.54*		

* 8 454 500/203 500

ANNEX 2

THE CONCENTRATION OF SUBSTANCES
SUGAR
Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	10	5	0
Soda with intense sweeteners	0	5	0
Battery	11.5	11.5	0
'Saft' 1:4	10	5	0
Blackberry 'saft'	8.3	4	0
Orangeflavoured [1] 'saft'	9.1	4.5	0
'Saft', energyreduced	0	5	0
Apple nectar	5.2	2.5	0
Concentrated blackberry'saft' [2]	50	50	50
Concentrated 'saft'[2]	41.7	41.7	41.7

1 Made from oranges
2 Only for cooking

ASPARTAME
Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	0	21.82	43.64
Soda with intense sweeteners	43.64	21.82	43.64
Battery	0	0	0
'Saft' 1:4	0	7.98	15.96
Blackberry 'saft'	0	7.98	15.96
Orangeflavoured [1] 'saft'	0	7.98	15.96
'Saft', energyreduced	15.96	7.98	15.96
Apple nectar	0	5	10
Concentrated blackberry'saft' [2]	0	0	0
Concentrated 'saft' [2]	0	0	0

1 Made from oranges
2 Only for cooking

ACESULFAME K
Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	0	4.91	9.82
Soda with intense sweeteners	9.82	4.91	9.82
Battery	0	0	0
'Saft' 1:4	0	6.27	12.54
Blackberry 'saft'	0	6.27	12.54
Orangeflavoured [1] 'saft'	0	6.27	12.54
'Saft', energyreduced	12.54	6.27	12.54
Apple nectar	0	5	10
Concentrated blackberry'saft' [2]	0	0	0
Concentrated 'saft' [2]	0	0	0

1 Made from oranges
2 Only for cooking

CYCKLAMATE
Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	0	0.22	0.45
Soda with intense sweeteners	0.45	0.22	0.45
Battery	0	0	0
'Saft' 1:4	0	0	0
Blackberry 'saft'	0	0	0
Orangeflavoured [1] 'saft'	0	0	0
'Saft', energyreduced	0	0	0
Apple nectar	0	0	0
Concentrated blackberry'saft' [2]	0	0	0
Concentrated 'saft' [2]	0	0	0

1 Made from oranges
2 Only for cooking

SACCHARINE

Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	0	0.01	0.02
Soda with intense sweeteners	0.02	0.01	0.02
Battery	0	0	0
'Saft' 1:4	0	0	0
Blackberry 'saft'	0	0	0
Orangeflavoured [1] 'saft'	0	0	0
'Saft', energyreduced	0	0	0
Apple nectar	0	0	0
Concentrated blackberry'saft' [2]	0	0	0
Concentrated 'saft' [2]	0	0	0

1 Made from oranges
2 Only for cooking

BENZOIC ACID
Foods other than drinks

Food	mg/100 g
Pickled cucumber	57.1
Pickled red beets	57.1
Mustard	35.8
Ketchup	39.9
Pumpkin	57.1
Sauerkraut (surkål)	107
Red whortleberry jam (tyttebærsyltetøy)	100
Jam	62.3
Blueberryjam	62.3
Apple sauce(eplemos)	62.3
Strawberryjam	45.5
Banana marmalade	0
Jam reduced sugar conten	62.3
Concentrated blackberry 'saft'[1]	80
'Saft', concentrated[1]	80
Crustaceans	200
Shrimp	200
Pickled herring	128.3
Herring	128.3
'Caviarmix' (kaviarmix)	200
'Caviar'	200
Pate made of roe and fish liver (svolværpostei/lofotpostei)	200
Mayonnaise	50
Mayonnaise, energyreduced	100
Mustard Sauce	100
Remoulade	50
Dressing thousand island	100
Thousand island, energyreduced	100
Prepared salads	126.2
Prepared salads, energyreduced	126.2
Shrimp salad	126.2
Breakfast salad	126.2
Cocoabased confectionary	150
Confectionary	150
Confectionary, filled	150
Chewing gum	150
Caramels	150
Liquorice	150
Jelly confectionary	150
Marshmellows	150
Marszpan	150
Caramel topping	150
Chocolate topping	150

1 Only for cooking

Drinks

Food	Current situation mg/100 g	50% scenario mg/100 g	100% scenario mg/100 g
Soda with sugar	4.77	9.66	14.55
Soda with intense sweeteners	14.55	9.66	14.55
Battery	14.99	14.99	14.99
'Saft' 1:4	4.83	5.04	5.25
Blackberry 'saft'	2.21	3.73	5.25
Orangeflavoured 'saft' [1]	5.52	5.38	5.25
'Saft', energyreduced	5.25	5.04	5.25
Apple nectar	0	2.62	5.25
Concentrated blackberry'saft' [2]	11.04	11.04	11.04
Concentrated 'saft' [2]	23.64	23.64	23.64

1 Made from oranges
2 Only for cooking

ANNEX 3

CURRENT SITUATION

Mean, median, 95th percentile consumption of sugared soft drinks, 'saft' and nectar g/person/day, all participants

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	1231	94	34	361
2-year-olds	1720	191	120	617
4-year-olds	391	209	188	533
9-year-olds	810	333	285	754
13-year-olds	1005	447	378	1056
Men	1291	280	126	1088
Women	1381	163	70	559

Mean, median, 95th percentile consumption of sugared soft drinks, 'saft' and nectar g/person/day, consumers only

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	886	131	60	513
2-year-olds	1605	205	137	634
4-year-olds	368	222	188	543
9-year-olds	779	346	300	758
13-year-olds	964	466	398	1079
Men	1042	349	180	1218
Women	1056	213	103	671

Mean, median, 95th percentile consumption of soft drinks, 'saft' and nectar with intense sweeteners, g/person/day, all participants

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	1231	21	0	120
2-year-olds	1720	35	0	240
4-year-olds	391	25	0	161
9-year-olds	810	45	0	275
13-year-olds	1005	54	0	322
Men	1291	79	0	419
Women	1381	102	0	512

Mean, median, 95th percentile consumption of soft drinks, 'saft' and nectar with intense sweeteners, g/person/day, consumers only

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	190	136	60	513
2-year-olds	426	141	60	547
4-year-olds	81	119	75	281
9-year-olds	216	170	115	481
13-year-olds	269	201	125	560
Men	452	226	94	981
Women	602	234	97	1006

100% SCENARIO

Mean, median, 95th percentile consumption of soft drinks, 'saft' and nectar with intense sweeteners, g/person/day, all participants

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	1231	115	51	480
2-year-olds	1720	226	154	729
4-year-olds	391	234	208	569
9-year-olds	810	378	352	818
13-year-olds	1005	501	438	1139
Men	1291	360	182	1300
Women	1381	265	133	1000

Mean, median, 95th percentile consumption of soft drinks, 'saft' and nectar with intense sweeteners, g/person/day, consumers only

Age groups	Number of individuals	Mean	Median	95th percentile
1-year-olds	934	152	86	481
2-year-olds	1636	237	154	743
4-year-olds	376	243	212	575
9-year-olds	787	389	358	822
13-year-olds	979	514	455	1143
Men	1124	413	234	1407
Women	1196	306	178	1043

ANNEX 4

AUTHORISED CONCENTRATIONS OF INTENSE SWEETENERS IN DIFFEENT CATEGORIES OF FOODS

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine (mg/l or mg/kg)	
1.1.2	Milk based beverages, and analogues, flavoured and/ or fermented		350	600	250	80	300	50	350	0	Energyreduced or with no added sugar
1.2.1.1	Fermented milk products, not post-heat treated		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
1.2.1.2	Fermented milk products, post-heat treated		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
1.2.2	Renneted milk-based products		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
1.7	Milk-based desserts		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
2.4	Fat-based desserts		350	1000	250	100	400	50	350		Energyreduced or with no added sugar
3	Edible ices		800	800	0	100	320	50	800	50	Energyreduced or with no added sugar
4.3.2	Fruit and vegetables in vinegar, oil and brine	Sweet-sour products	200	300	0	160	180	100	200	0	Energyreduced or with no added sugar
4.3.3	Canned or bottled fruit and vegetables	Fruit products	350	1000	1000	200	400	50	350	0	Energyreduced or with no added sugar
4.3.4.2	Fruit-based spreads, other than 4.2.4.1		1000	1000	1000	200	400	50	1000	0	Energyreduced
4.3.6	Fruit- and vegetable preparations		350	1000	250	200	400	50	350	0	Energyreduced

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine	
4.3.7	Fruit- and vegetable based desserts		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
5.1	Cocoa- and chocolate products.	Chocolate products	500	2000	0	500	800	100	500	50	Energyreduced or with no added sugar
5.2	Sugar confectionary except products in 5.1 and 5.3		500	1000	0	500	1000	100	500	50	No added sugar
5.2	Sugar confectionary except products in 5.1 and 5.3	Tablet-form confectionary	500	0	0	0	200	0	0	0	No added sugar
5.2	Sugar confectionary except products in 5.1 and 5.3	Breath-freshening microsweets	2500	6000	0	3000	2400	400	2500	0	No added sugar
5.2	Sugar confectionary except products in 5.1 and 5.3	Cocoa- or dried-fruit-based confectionary	500	2000	0	500	800	100	500	50	Energyreduced or with no added sugar
5.2	Sugar confectionary except products in 5.1 and 5.3	Starch-based confectionary	1000	2000	0	300	1000	150	1000	50	Energyreduced or with no added sugar
5.3	Chewing gum		2000	5500	0	1200	3000	400	2000	50	No added sugar
6.3	Breakfast cereals	Products with a fibre content of more than 15% and containing at least 20% bran	1200	1000	0	100	400	50	1000	0	Energyreduced or with no added sugar
6.5	Cereal- or starch based desserts		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine	
7.2	Fine bakery wares	Special nutritional uses	1000	1700	1600	170	700	150	1000	0	
7.2	Fine bakery wares	Cornets and wafers for ice cream	2000	0	0	800	800	50	0	0	No added sugar
9.4.1	Fish and fish products, marinated and/or in aspic	Marinades and sweet/sour products	200	300	0	160	120	30	200	0	
9.4.2	Fish and fish products, pickled and/or in brine	Marinades and sweet/sour products	200	300	0	160	120	30	200	0	
9.5	Preserved fishproducts	Marinades and sweet/sour products	200	300	0	160	120	30	200	0	
10.5	Eggbased desserts		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar
12.4	Mustard		350	350	0	320	140	50	350	0	
12.5	Soups and bouillons	Soups	110	110	0	110	45	50	110	0	Energyreduced
12.6.1	Emulgated sauces		350	350	0	160	450	50	350	0	
12.6.2	Non-emulgated sauces		350	350	0	160	450	50	350	0	
12.7	Salads and cocoa-, milk-, dried-fruit- or fat-based sandwich spreads	Sandwich spreads	1000	1000	500	200	400	50	1000	0	Energyreduced or with no added sugar
13.3	Dietary food for special medical purposes except those in 13.1 and 13.2		450	1000	400	200	320	100	450	0	

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine	
13.4	Foods intended for use in energyreduced diets for weight reduction		450	800	400	240	400	100	450	0	
13.6	Food supplements	In liquid form	350	600	400	80	240	100	500	0	
13.6	Food supplements	In solid form	500	2000	500	500	800	100	500	0	
13.6	Food supplements	Based on vitamins and/or mineral elements supplied in a syrup type or chewable form	2000	5500	1250	1200	2400	400	2000	400	
14.1.2	'Saft' og 'sirup' based on fruit and vegetables	Fruit based products	350	600	250	80	300	30	350	0	Energyreduced or with no added sugar
14.1.3	Fruit- and vegetable based nectar	Fruit based products	350	600	250	80	300	30	350	0	Energyreduced or with no added sugar
14.1.4	Waterbased flavoured drinks		350	600	250	80	300	30	350	0	Energyreduced or with no added sugar
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)		25	25	0	0	10	10	25	0	Energyreduced
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)	Alcohol-free beer or with an alcohol-content not exceeding 1,2% vol	350	600	0	80	250	10	350	0	

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)	Brown beers of the 'oud bruin' type	350	600	0	80	250	10	350	0
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)	Bière de table/Tafelbier/Table beer (original wort conten less than 6%) except for 'Obergäriges Einfachbier'	350	600	0	80	250	10	350	0
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)	Beers with a minimum acidity of 30 milli-equivalents expressed as NAOH	350	600	0	80	250	10	350	0
14.2.2	Apple- and pear based cider		350	600	0	80	50	20	350	0
14.2.6.2	Sprit drinks containing less than 15% alcohol by volume		350	600	0	80	250	30	350	0
14.2.7	Drinks consisting of a mixture of a non-alcoholic drink and beer, cider, perry, spirits or wine		350	600	0	80	250	30	350	0
15.1	Cereal-, starch, potato-based snacks	Ready to eat, prepacked, dry, savoury starch-products	350	500	0	100	200	60	500	0

Food category	Foodstuff	Limited to:	Acesulfame K (mg/l or mg/kg)	Aspartame (mg/l or mg/kg)	Cyclamic acid and cyclamates (mg/l or mg/kg)	Saccharine and saccharinates (mg/l or mg/kg)	Sucralose (mg/l or mg/kg)	Neohesperidine DC (mg/l or mg/kg)	Aspartame-Acesulfame salt (mg/l or mg/kg)	Thaumatine	
15.2	Coated nuts	Flavoured prepacked savoury coated nuts	350	500	0	100	200	60	500	0	
16.1	Water-based flavoured desserts		350	1000	250	100	400	50	350	0	Energyreduced or with no added sugar

ANNEX 5

AUTHORISED CONCENTRATIONS OF BENZOIC ACID AND OTHER PRESERVATIVES IN DIFFERENT CATEGORIES OF FOODS

Food category	Foodstuff	Limited to:	Benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid, sorbates and benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid and sorbates, benzoic acid and benzoates and p-hydroxybenzoates (mg/l or mg/kg)
1.7	Dairy based desserts	Non-heat treated products		300	
4.3.2	Fruit and vegetables in vinegar, oil and brine	Olives	500	1000	
4.3.2	Fruit and vegetables in vinegar, oil and brine	Vegetables except olives		2000	
4.3.4.2	Fruit-based spreads, other than 4.2.4.1		500	1000	
4.3.4.2	Fruit-based spreads, other than 4.2.4.1	Dulce de membrillo	1000		
4.3.4.2	Fruit-based spreads, other than 4.2.4.1	Mermelada		1500	
4.3.5	Candied fruis and vegetables			1000	
4.3.6	Fruit- and vegetable preparations	Olive-based preparations	500		
4.3.6	Fruit- and vegetable preparations	Cooked red bete	2000		
4.3.7	Fruit- and vegetable based desserts	Fruktgrød and Rote Grütze	500		
5.2	Sugar confectionary except products in 5.1 and 5.3				1500
5.3	Chewing gum			1500	

Food category	Foodstuff	Limited to:	Benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid, sorbates and benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid and sorbates, benzoic acid and benzoates and p-hydroxybenzoates (mg/l or mg/kg)
8.2.1	Non-heat treated meat products in whole pieces or cuts	Surface treatment of dry products			quantum satis
8.2.2	Heat treated meat products in whole pieces and cuts	Surface treatment of dry products			quantum satis
8.3.1	Non-heat treated comminuted meat meat products	Surface treatment of dry products			quantum satis
8.3.2	Heat treated comminuted meat products	Surface treatment of dry products			quantum satis
9.3.1.2	Heat-treated crustacean and mollusks	Shrimps		2000	
9.3.1.2	Heat-treated crustacean and mollusks	Crangon crangon and Crangon vulgaris		6000	
9.3.3	Smoked, dried an/or salted fish and fish products	Salted, dry fish		200	
9.4.1	Fish and fish products, marinated and/or in aspic	Fish products		2000	
9.4.2	Fish and fish products, pickled and/or in brine	Fish products		2000	
9.4.3	Salmon substitutes, caviar and other fish roe products			2000	

Food category	Foodstuff	Limited to:	Benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid, sorbates and benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid and sorbates, benzoic acid and benzoates and p-hydroxybenzoates (mg/l or mg/kg)
9.4.4	Other semi-preserved fish products than 9.4.1-9.4.3	Fish products		2000	
10.2	Liquid egg products			5000	
12.2	Herbs, spices, seasonings and condiments	Seasonings and condiments		1000	
12.4	Mustard			1000	
12.5	Soup and bouillons	Liquid soups and broths, excluding canned		500	
12.6.1	Emulsified sauces		500	1000	
12.6.1	Emulsified sauces	Fat content less thant 60%	1000	2000	
12.6.2	Non-emulsified sauces			1000	
12.7	Salads and cocoa-, milk-, dried-fruit- or fat-based sandwich spreads	Fruit based spreads	500	1000	
12.7	Salads and cocoa-, milk-, dried-fruit- or fat-based sandwich spreads	Prepared salads		1500	
13.3	Dietary food for special medical purposes except those in 13.1 and 13.2			1500	
13.4	Foods intended for use in energyreduced diets for weight reduction			1500	
13.6	Food supplements	Liquid products			2000

Food category	Foodstuff	Limited to:	Benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid, sorbates and benzoic acid and benzoates (mg/l or mg/kg)	Sorbic acid and sorbates, benzoic acid and benzoates and p-hydroxybenzoates (mg/l or mg/kg)
14.1.2	'Saft' og 'sirup based on fruit and vegetables	Søt 'saft' and søtet 'saft'	200		
14.1.2	'Saft' og 'sirup based on fruit and vegetables	Grape juice, unfermented for sacramental use			2000
12.1.4	Waterbased flavoured drinks		150	250	
12.1.4	Waterbased flavoured drinks	Mehu and Makeututtu	150	250	
12.1.5	Coffee, coffee analogues, tea, herbal tea and other hot drinks except cocoa	Liquid tea concentrates		600	
12.1.5	Coffee, coffee analogues, tea, herbal tea and other hot drinks except cocoa	Liquid fruit and herbal infusion concentrates		600	
14.2.1	Alcohol-based drinks (including low-alcoholic and non-alcoholic drinks)	Alcohol free beer in keg	200		
12.2.6.2	Sprit drinks containing less than 15% alcohol by volume		200		
16.2	Toppings and coatings	Aspic	500		

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