British Journal of Nutrition (2005), **93**, 114–124
DOI: 10.1079/BJN20051448

Comparison of methods to estimate non-milk extrinsic sugars and their application to sugars in the diet of young adolescents

Sarah A. M. Kelly[1], Carolyn Summerbell[2], Andrew J. Rugg-Gunn[1], Ashley Adamson[3], Emma Fletcher[3] and Paula J. Moynihan[1]*

[1]*School of Dental Sciences, University of Newcastle, Framlington Place, Newcastle upon Tyne NE2 4BW, UK*
[2]*School of Health, University of Teesside, Middlesbrough TS1 3BA, UK*
[3]*Human Nutrition Research Centre, University of Newcastle, Wellcome Laboratories, Royal Victoria Infirmary, Newcastle upon Tyne NE1 4LP, UK*

(Received 18 August 2004 – Revised 31 January 2005 – Accepted 1 February 2005)

Consistent information on the non-milk extrinsic sugars (NMES) content of foods and the NMES intake by the population is required in order to allow comparisons between dietary surveys. A critical appraisal of methods of NMES estimation was conducted to investigate whether the different published methods for estimating the NMES content of foods lead to significantly different values for the dietary intake of NMES by children and to consider the relative practicality of each method. NMES values of foods were calculated using three different published descriptions of methods of NMES estimation, and the values were compared within food groups. Dietary intake values for English children aged 11–12 years were calculated using each method and compared in terms of overall NMES intake and the contribution of different food groups to NMES intake. There was no significant difference in the dietary intake of NMES in children between the method used in the National Diet and Nutrition Surveys (NDNS) (81·9 g/d; 95 % CI 79·0, 84·7) and a method developed by the Human Nutrition Research Centre (84·3 g/d; 95 % CI 81·4, 87·2) at Newcastle University, UK, although the latter gave slightly higher values. An earlier method used by the Ministry of Agriculture, Food and Fisheries gave significantly higher values than the other two methods (102·5 g/d; 95 % CI 99·3, 105·6; $P<0·05$). The method used in the NDNS surveys and the method used by the Human Nutrition Research Centre at Newcastle University are both thorough and detailed methods that give consistent results. However, the method used in the NDNS surveys was more straightforward to apply in practice and is the best method for a single uniform approach to the estimation of NMES.

Sugars: Non-milk extrinsic sugars: Dietary intakes

Sugars are the most important dietary cause of caries in children and adults (Sheiham, 2001). In the UK, £1·5 billion (direct costs) are spent each year on treating dental caries (Rugg-Gunn, 2001). Both the frequency of consumption and the total amount of sugars are important in the aetiology of caries (Sheiham, 2001; World Health Organization, 2003). In 1989, a Committe on Medical Aspects of Food Policy (COMA) report classified sugars, mainly for health education purposes, into intrinsic and extrinsic sugars (Department of Health, 1989). Extrinsic sugars were classified as those sugars which were not located within the cellular structure of food, and were further divided into milk sugars and non-milk extrinsic sugars (NMES). There is no evidence that sugars naturally incorporated into the cellular structure of foods (intrinsic sugars) or lactose in milk and milk products (milk sugars) are harmful to health. However, NMES are harmful to teeth (Department of Health, 1989) and may be associated with obesity (Ludwig *et al.* 2001; World Health Organization, 2003) and diabetes (Schulze *et al.* 2004).

The term NMES has generally only been adopted by the UK, although ‘free sugars’ is more internationally accepted as it was used by the WHO in the Technical Series Report *Diet, Nutrition and the Prevention of Chronic Diseases* (World Health Organization, 1990). This WHO report recommended that the consumption of free sugars should contribute no more than 10 % of energy intake. There are, however, no studies in the literature in which free sugars in foods or diets have been estimated and reported. The term ‘free sugars’ is, however, synonymous with the term NMES, and if these terms are to be adopted in research worldwide, a good, clear quantitative method for the estimation of NMES or free sugars is required.

The recommendation of the 1989 COMA report was that NMES consumption should be reduced (Department of Health, 1989). The subsequent 1991 COMA report on dietary reference values (Department of Health, 1991) stated that NMES should contribute no more than 10 %, or 60 g/d, to energy intake. Recent reports reiterate the importance of limiting NMES (or ‘free sugars’) to prevent dental caries (Sheiham, 2001; World Health Organization, 2003; Moynihan & Peterson, 2004). To achieve and monitor this public health goal, consistent information on the NMES content of foods and the NMES intake of the population is required in order to allow comparisons between dietary surveys. However, since NMES are chemically indistinguishable from other sugars, they

Abbreviations: COMA, Committe on Medical Aspects of Food Policy; FSA, Food Standards Agency; HNRC, Human Nutrition Research Centre; MAFF, Ministry of Agriculture, Food and Fisheries; NDNS, National Diet and Nutrition Survey; NMES, non-milk extrinsic sugars.

* **Corresponding author:** Dr Paula Moynihan, fax +44 (0) 191 222 5928, email p.j.moynihan@ncl.ac.uk

cannot be quantified by conventional techniques used for the analysis of sugars in foods (Johnson *et al.* 1996). Those surveys in which NMES intake has been reported have estimated the NMES of foods based on the examination of recipes or other data from the available food tables. The authors have previously published a comprehensive literature review of the different methods of NMES estimation (Kelly *et al.* 2003).

Three of the five methods of NMES estimation that were identified were chosen for the present study. These three methods were:

1. the method used by the Foods Standards Agency (FSA) in the National Diet and Nutrition Surveys (NDNS; Buss *et al.* 1994; Gregory *et al.* 1995, 2000; Finch *et al.* 1998);
2. an earlier Ministry of Agriculture, Food and Fisheries (MAFF; now FSA) method reported in *The Dietary and Nutritional Survey of British Adults – Further Analysis* (Mills, 1994);
3. a method that has been used by the Human Nutrition Research Centre (HNRC) at Newcastle University, UK (Rugg-Gunn *et al.* 1993).

The NDNS method was selected as it is the 'standard' method used consistently in the NDNS published since 1995. The earlier MAFF method was chosen because it appeared to be a simple and relatively easy method to apply; therefore, this method could be useful to countries that do not have access to FSA food composition databases and could aid in obtaining more comprehensive data on NMES from worldwide populations. If a simple method also makes little difference to dietary outcomes, it could be argued that the effort required to apply the other methods is not warranted.

The HNRC method is currently used in cross-sectional studies investigating dietary trends in adolescents over the past three decades (Rugg-Gunn *et al.* 2005) and has developed over time from a method based on added sugars. The other two published methods, which were not selected for this analysis, appeared to be similar and were both based on the NDNS method (Bolton-Smith & Woodward, 1994; Drummond & Kirk, 1998).

The aims of the work were:

1. to estimate the NMES content of all foods in the food tables in the fifth edition of *McCance and Widdowson's The Composition of Foods* (Holland *et al.* 1991) and to compare the values obtained by the three methods;
2. to compare the NMES intakes of young English adolescents (using a recently collected database of food-intake records) calculated using the three methods, for all children and for each gender separately, and to calculate the contribution of different food groups to NMES intake;
3. to assess the advantages and disadvantages of each method in terms of practicality, degree of complexity and labour intensity.

Methods

Published methods of NMES estimation

The three methods of NMES estimation are listed in Table 1, along with published details of each method as described in the literature. It should, however, be noted that in each case the details of the methods used were considerably more complex than (or different from) those of the outline method described in the literature. It was not possible to replicate any of the methods based solely on the limited descriptions given in the published literature, without further clarification from the authors of the respective studies. These further details of the methods are given in Appendix 1.

Even with this additional information from the authors, there were a number of foods and types of food for which even the additional guidelines supplied were insufficient when the NMES values were calculated, and it was not clear how to calculate the NMES value. The assumptions made for such foods are also listed in Appendix 1.

Calculation of NMES values for food tables

The NMES values (g/100 g) for all foods in the fifth edition of *McCance and Widdowson's The Composition of Foods* (Holland *et al.* 1991) were estimated for each of the three methods, and the calculated figures were entered into fields in the computerised food tables held by the HNRC at Newcastle University in order to carry out the dietary intake analysis.

In order to investigate between-method differences for the NMES content of different types of foods, those foods known to make a substantial contribution to NMES were grouped together according to the classifications in the fifth edition of the food tables: biscuits, cakes, confectionery (chocolate and non-chocolate confectionery), breakfast cereals, sugars, syrups and preserves, ice creams, yoghurts (including fromage frais), fruit juices, fruit, soft drinks, cereal products and milk products. The data in each food group were

Table 1. Summary of published descriptions of methods for non-milk extrinsic sugar (NMES) estimation

Method	Published details of NMES method	Further information
NDNS	'Non-milk extrinsic sugars = All sugars in fruit juices, table sugar, honey, sucrose, glucose and glucose syrups added to food plus 50 % of the sugars in canned, stewed, dried or preserved fruits' (Buss *et al.* 1994; Gregory *et al.* 1995, 2000; Finch *et al.* 1998)	This method has been used by the Food Standards Agency (formerly MAFF) in the NDNS published since 1995. The actual method used is substantially more complex than the published details (Appendix 1)
MAFF	'Non-milk extrinsic sugars intakes estimated from total sugars by deducting the sugars from liquid cow's milk' (Mills, 1994)	This method precedes the above NDNS method and was used by MAFF in *The Dietary and Nutritional Survey of British Adults – Further Analysis* (Mills, 1994), which was a re-analysis of data collected in 1990. The actual method used was different from the details of the method published. Further details are given in Appendix 1
HNRC	'Added sugars plus sugars from fruit in fruit juices and other soft drinks ... Fruit sugars deriving from the fruit in jams and yoghurts classified as intrinsic' (Rugg-Gunn *et al.* 1993)	This method has been used and developed over time at the HNRC. The actual method used is substantially more complex than the published details. Further details are given in Appendix 1

NDNS, National Diet and Nutrition Surveys; MAFF, Ministry of Agriculture, Food and Fisheries; HNRC, Human Nutrition Research Centre, Newcastle University, UK.

compared as MAFF *v.* NDNS, NDNS *v.* HNRC, and MAFF *v.* HNRC. Mean NMES values for each of these thirteen groups of food were calculated. These mean values were compared between the three methods, and the mean differences between the methods and 95 % CI were calculated ($P<0{\cdot}05$). The values obtained between methods within food groups were also compared by paired *t* test (two-tailed).

Application of calculated NMES values to dietary intake data

The mean daily intake of NMES by schoolchildren was calculated from existing data held in the Northumberland 2000 Microsoft Access database developed at Newcastle University. The database incorporates dietary-intake data collected from a study of 424 (196 boys, 228 girls) Northumbrian children aged 11–12 years in 2000 (Rugg-Gunn *et al.* 2005). Children completed two estimated 3 d food diaries, and the results are reported as 6 d means. The mean daily NMES intake of all the children, and of boys and girls separately, was calculated. In addition, mean intakes of NMES were calculated for thirteen groups of foods known to make a substantial contribution to overall NMES consumption. Not all the children consumed foods from some of the food groups (i.e. those who ate no foods from a food group contributed 0 g/d). The number of children who did eat foods from each food group has been reported. Food groups were classified according to FSA classifications for foods in the food tables (Holland *et al.* 1991).

Data analysis was by SPSS (Statistical Package for Social Science; SPSS Inc., Chicago IL, USA) version 10. The mean dietary intake of NMES (g/d) and the contribution to percentage energy intake were reported with 95 % CI ($P<0{\cdot}05$). The NMES intakes were compared between methods using Bland–Altman plots (Bland & Altman, 1986).

Results

NMES values calculated for foods in the fifth edition of McCance and Widdowson

The MAFF method gave significantly higher NMES values (g/100 g) than the NDNS or HNRC methods for every food group (Table 2) except fruit juices, soft drinks and confectionery, which were equivalent. All three methods gave the same values for soft drinks and fruit juices, and the MAFF and HNRC methods gave equivalent values for chocolate confectionery, soft drinks and fruit juices.

There was little significant difference between the NDNS and HNRC methods except for the confectionery, fruit and milk groups. The largest significant difference between the NDNS method and the HNRC method was for chocolate confectionery, for which the HNRC method gave higher NMES values. Both methods gave the same values for fruit juices, soft drinks, yoghurts and fromage frais.

Dietary intake of NMES

When the NMES values estimated by the three methods for the foods in the McCance and Widdowson food tables were used to calculate the schoolchildren's mean dietary NMES intakes (Table 3), the MAFF method resulted in significantly higher intakes compared with either the NDNS or the HNRC method. There was no statistically significant difference between the

Table 2. Mean differences in non-milk extrinsic sugar value between the three methods, for each of thirteen food groups in *McCance and Widdowson's The Composition of Foods* (Holland *et al.* 1991)

			Mean difference (g/100 g)					
			NDNS–HNRC		MAFF–NDNS		MAFF–HNRC	
Food group	Number of foods in sample	Food codes in the fifth edition	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI
Biscuits	16	93–108	−1·5	−3·2, 0·2	3·4*	0·2, 6·7	1·9*	0·2, 1·9
Cakes	15	109–123	−0·4	−1·8, 1·0	5·3*	1·9, 8·8	4·9*	1·5, 8·4
Breakfast cereals	28	65–92	−0·2	−2·2, 1·8	3·5*	2·4, 4·7	3·3*	1·1, 5·5
Sugars, syrups and preserves	15	999–1013	5·6	−2·5, 13·8	4·0	−0·1, 8·1	9·6*	1·.4, 17·9
Ice creams	11	262, 264–273	0·05	−0·1, 0·2	4·9*	3·2, 6·5	4·9*	3·3, 6·5
Yoghurts, fromage frais	14	251–261 239–241	0·00		6·0*	4·7, 7·4	6·0*	4·7, 7·4
Fruit juices	7	1087–1093	0·00		0·00		0·00	
All cereal products	180	1–180	0·5	−0·1, 1·1	3·4*	2·8, 4·0	3·9*	3·1, 4·7
All milk products	109	181–289	0·2*	0·1, 0·4	3·0*	1·7, 4·3	3·2*	1·9, 4·4
All soft drinks	14	1080–1093	0·00		0·00		0·00	
All confectionery	20	1014–1033	−3·2*	−4·9, −1·5	3·2*	1·6, 4·9	0·05	−0·05, 0·15
Chocolate confectionery	11	1014–1024	−5·7*	−7·8, −3·7	5·7*	3·7, 7·8	0·00	
All fruit	120	852–971	2·5*	1·0, 4·0	8·0*	6·5, 9·4	10·4*	7·7, 13·2

NDNS, National Diet and Nutrition Surveys; HNRC, Human Nutrition Research Centre, Newcastle University, UK; MAFF, Ministry of Agriculture, Food and Fisheries.
* Statistically significant difference ($P<0{\cdot}05$).

Table 3. Mean non-milk extrinsic sugar (NMES) and energy intakes for children aged 11–12 years: comparison between the three different methods of NMES estimation

	NDNS		HNRC		MAFF	
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI
Boys (*n* 196)						
NMES (g/d)	87·8	83·0, 92·5	90·6	(85·8, 95·5)	108·9*	103·7, 114·1
% energy (from NMES)	16·6	16·0, 17·2	17·2	(16·5, 17·8)	20·7*	20·0, 21·3
Girls (*n* 228)						
NMES (g/d)	76·8	73·5, 80·1	78·9	(75·5, 80·2)	97·0*	93·2, 100·6
% energy (from NMES)	16·3	15·7, 16·8	16·7	(16·2, 17·2)	20·6*	20·0, 21·1
All (boys and girls) (*n* 424)						
NMES (g/d)	81·9	79·0, 84·7	84·3	(81·4, 87·2)	102·5*	99·3, 105·6
% energy (from NMES)	16·4	16·0, 16·8	16·9	(16·5, 17·3)	20·6*	20·2, 21·0

NDNS, National Diet and Nutrition Surveys; HNRC, Human Nutrition Research Centre, Newcastle University, UK; MAFF, Ministry of Agriculture, Food and Fisheries.
* Statistically significant difference ($P < 0·05$).

mean intake calculated by the NDNS method and by the HNRC method, although the HNRC method gave a slightly higher value (a difference of 2·4 g/d). Similar results were seen when the dietary intake data were analysed separately for boys and girls (Table 3). There was also no statistically significant difference between mean percentage energy from NMES between the NDNS and HNRC methods.

Bland–Altman plots (Bland & Altman, 1986, 1995; Figs. 1, 2 and 3) can be used to show the relationship between the difference in the dietary NMES intake between two methods and the mean dietary NMES intake for the two methods. If the maximum difference between the two methods is within two standard deviations of the mean difference (95 % limits of agreement), the methods can be considered to be interchangeable as long as the differences between the methods are not of clinical significance. The reference lines in Figs. 1, 2 and 3 show the 95 % limits of agreement and the mean differences between the methods.

In Fig. 1, nineteen points lie outside the limits of agreement, so the MAFF and NDNS methods cannot be considered to be interchangeable. In Fig. 2, twenty points fall outside the limits of agreement, so the MAFF and HNRC methods are also not interchangeable. For both graphs, even within the limits of agreement, the differences in dietary intake for the same individual calculated by the two methods can be up to about 35 g/d, which would be considered to be clinically significant, for example if reported in a dietary survey.

From Fig. 3, the NDNS and HNRC methods also cannot be considered to be interchangeable, as twenty-two points fall outside the 95 % limits of agreement. Even within the limits of agreement, the difference in NMES intake for an individual calculated by the two different methods can be up to about 9 g/d.

All the graphs demonstrate a proportional bias, i.e. as the mean intake becomes larger, the difference in dietary intake values between the methods also tend to increase, but this effect is less marked in Fig. 3.

Contribution of food groups to NMES intake by children

Table 4 shows the contribution of each food group to NMES intake (g/d) for each of the three methods. As previously discussed, the MAFF method gives significantly higher values for dietary intakes of NMES than the other two methods when the overall intake is compared, but, within the individual food groups examined, there was no statistically significant difference between the methods, except for fruit.

The MAFF method gives higher values for a number of food groups (breakfast cereals, biscuits, cakes, buns and pastries, puddings, ice creams) but, except for fruit, the differences were not statistically significant within the food groups. The biggest differences were between the MAFF and NDNS methods for breakfast cereals, biscuits and chocolate confectionery. However, the biggest difference between any of these groups was for breakfast cereals (1·1 g/d, 95 % CI 0·6, 1·8) and chocolate confectionery (1·1 g/d, 95 % CI 0·2, 1·5) between the MAFF and NDNS methods.

A simplified description of the methods of NMES estimation within food groups and an overview of the main differences between the methods is given in Table 5.

Discussion

The mean dietary intake of a population is the measure usually reported in dietary surveys. Mean intakes calculated in this study show little statistically significant difference between the NDNS and HNRC methods and much higher values for the earlier MAFF method. Bland–Altman plots have, however, demonstrated that the NDNS and HNRC methods are not interchangeable and that, at an individual level, the limits of agreement can be wide.

The simple MAFF method is effectively a 'total sugars' method. It assumes that all sugars in foods are NMES sugars, except for sugars in liquid milk. This led to an overall higher estimation of NMES content as all sugars are incorporated as NMES even if the food does not contain added or extrinsic sugars. For example, in most types of bread, the NMES content by the HNRC and NDNS methods is zero as there is negligible added sugar, but in the MAFF method all the intrinsic sugars in flour and grains are included as NMES. When all foods are taken into account, the MAFF method gives significantly higher values for overall intake of NMES in children than the other two methods (Table 3). However, it can be seen from Table 4 that there is no significant difference between the MAFF method and the other two methods in dietary intakes of NMES within those food groups commonly associated with NMES intake, except for fruit. There is a marked difference for 'other' food groups between the MAFF method and the NDNS and HNRC methods, and this is attributed to the cumulative effect

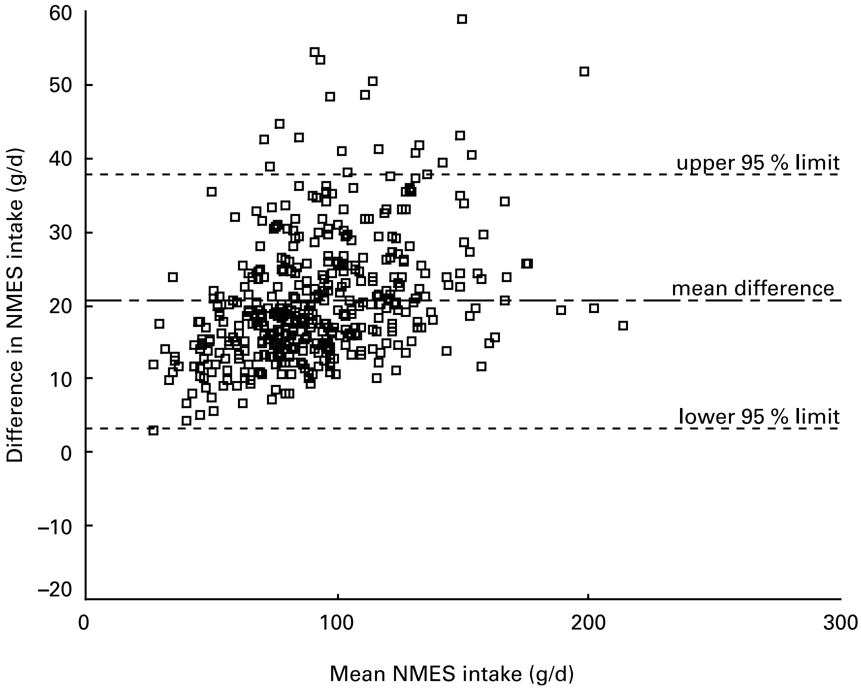

Fig. 1. Bland–Altman plot of the difference in the non-milk extrinsic sugars (NMES) intake of 424 young English adolescents calculated using the Ministry of Agriculture, Food and Fisheries and National Diet and Nutrition Surveys methods, by mean NMES intake for these two methods. The interrupted lines show the 95 % limits of agreement.

of intrinsic sugars in flour and grains being classed as NMES by this method.

For fruit, the MAFF method gives a much higher mean NMES intake than the NDNS or HNRC methods, as this method includes all fruit sugars as NMES. There is no significant difference between the NDNS and HNRC methods, but the mean NMES intake from fruit by each of these methods is negligible (Table 4). This finding suggests that, for this population of children studied with a very low fruit intake, the intricacy of estimating 50 % of sugars in processed fruit as NMES by the NDNS method makes little difference to the overall NMES values estimated. For dried fruit, jams, canned fruit and stewed fruit, half of the fruit sugar was considered to be

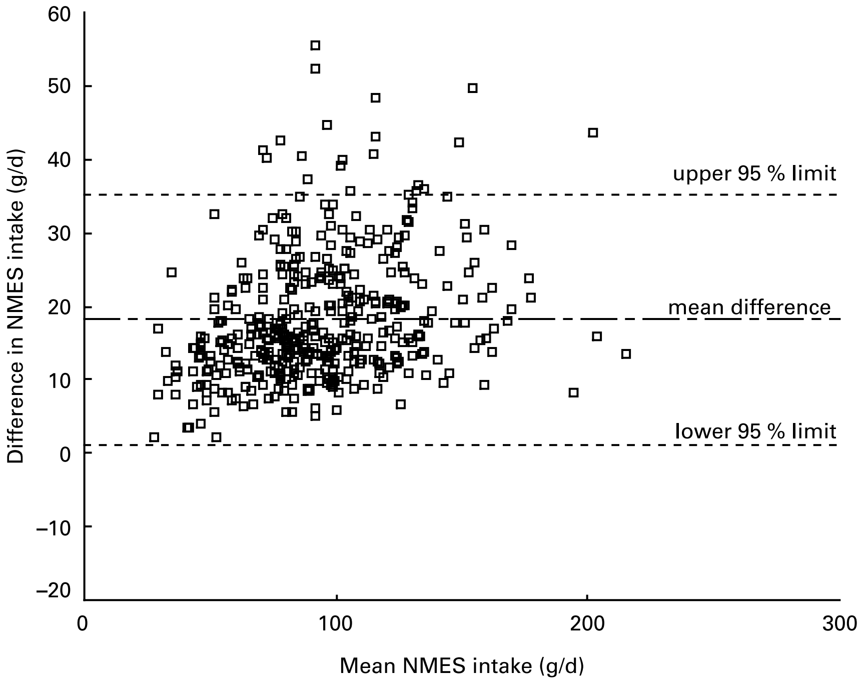

Fig. 2. Bland–Altman plot of the difference in the non-milk extrinsic sugars (NMES) intake of 424 young English adolescents calculated using the Ministry of Agriculture, Food and Fisheries and the Human Nutrition Research Centre methods, by mean NMES intake for these two methods. The interrupted lines show the 95 % limits of agreement.

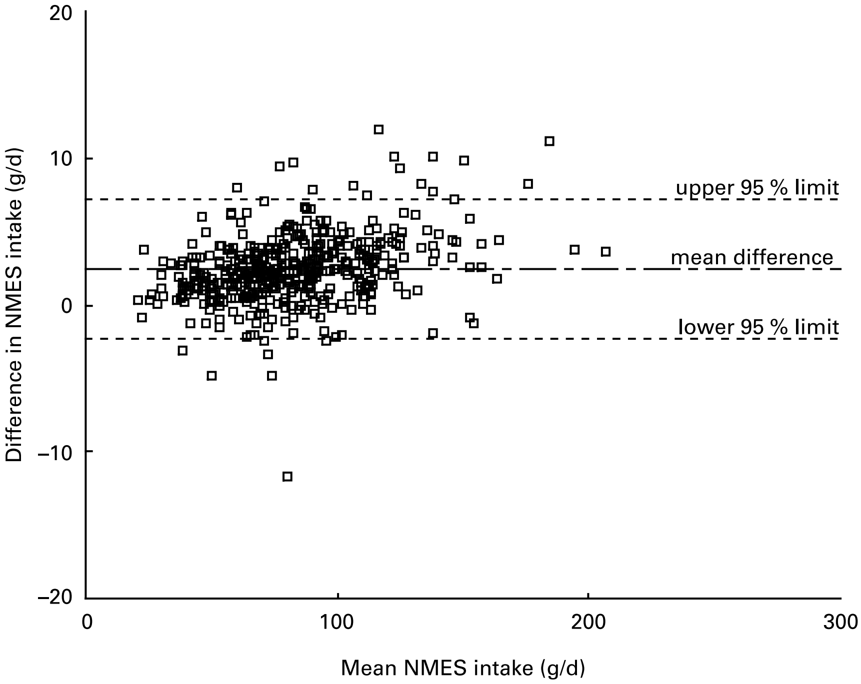

Fig. 3. Bland–Altman plot of the difference in the non-milk extrinsic sugars (NMES) intake of 424 young English adolescents calculated using the Human Nutrition Research Centre and the National Diet and Nutrition Surveys methods, by mean NMES intake for these two methods. The interrupted lines show the 95 % limits of agreement.

intrinsic and half NMES in the NDNS method, whereas all fruit sugar was intrinsic in the HNRC method. Unless the consumption of fruit in a given population is extremely high, this additional complexity may not be justified by improvements in the accuracy of estimation.

Other than fruit, the main contribution to the difference between the MAFF method and the other two methods comes from the ‘other food groups’ category, i.e. those food groups which do not normally contribute significantly to NMES content. This is likely to be attributed to the cumulative effect of the intrinsic sugars in grains being incorporated as NMES in the MAFF method.

The impact of the three different methods of NME sugars estimation on frequency of intake was not calculated in the present analysis. There are unlikely to be any differences in frequency of intake between the NDNS and HNRC methods because the only between-method differences relate to the proportions of NMES in the food rather than to whether or not NMES is present in the food. As the MAFF method classifies sugars in all foods except liquid milk as NMES, it is, however, likely to considerably overestimate frequency of intake.

The MAFF method was reported in the national dietary survey of adults (Mills, 1994) conducted prior to 1995 and preceded the

Table 4. Contribution of food groups to non-milk extrinsic sugar (NMES) intake (g/d) of 424 young adolescents calculated for the three NMES estimation methods

(Lines are means with 95 % CI)

			Mean NMES intake (g/d)					
			NDNS		MAFF		HNRC	
Selected food group	Description	Number of children eating foods from group	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI
AI	Breakfast cereals	384	6·8	6·1, 7·4	7·9	7·2, 8·6	7·6	6·9, 8·3
AM	Biscuits	395	6·8	6·2, 7·3	7·6	7·0, 8·2	7·0	6·5, 7·6
AN	Cakes	325	6·4	5·8, 7·0	6·9	6·3, 7·6	6·6	6·0, 7·2
AP	Buns and pastries	192	1·0	0·8, 1·2	1·5	1·2, 1·7	1·0	0·8, 1·2
AS	Puddings	152	1·3	1·0, 1·5	1·4	1·2, 1·7	1·1	0·9, 1·3
SC	Sugars, syrups and preserves	309	4·9	4·3, 5·4	4·9	4·3, 5·5	4·6	4·0, 5·2
SEA	Confectionery (chocolate)	372	8·9	8·1, 9·7	10·0	9·1, 10·9	10·0	9·1, 10·9
SEC	Confectionery (non-chocolate)	343	5·3	4·6, 5·9	5·3	4·6, 5·9	5·3	4·6, 5·9
BP	Ice creams	186	1·7	1·4, 2·0	2·3	1·9, 2·7	1·7	1·4, 2·0
PE	Fruit juices	402	12·7	11·6, 13·8	12·7	11·6, 13·8	12·7	11·6, 13·8
PCA/PCC	Carbonated drinks/cordials	401	19·6	18·2, 21·1	19·6	18·2, 21·1	19·6	18·2, 21·1
FA	Fruit (all fruit including canned, processed and dried fruit)	298	0·3	0·2, 0·4	5·1	4·5, 5·6	0·2	0·1, 0·3
Others	Total of other food groups		6·2		17·3		6·9	
All	Total of all food groups	424	81·9	79·0, 84·7	102·5	99·3, 105·6	84·3	81·4, 87·2

NDNS, National Diet and Nutrition Surveys; MAFF, Ministry of Agriculture Food and Fisheries; HNRC, Human Nutrition Centre, Newcastle University, UK.

Table 5. Comparison of methods of estimation of non-milk extrinsic sugar (NMES) for some food groups

Food group	(1) NDNS method	(2) MAFF method	(3) HNRC method	Comments
Bread	All sugars intrinsic	All NMES = total sugars	All sugars intrinsic	Methods 1 and 3 the same
Breakfast cereals (without fruit)	Sucrose NMES, other sugars intrinsic	All NMES = total sugars	Added sugars NMES, natural sugar intrinsic	Methods 1 and 3 similar
Breakfast cereals (with fruit)	Dried fruit sugar half intrinsic, half NMES	All NMES = total sugars	Dried fruit sugar all intrinsic	
Biscuits, cakes	Sugars from flour intrinsic, other sugars NMES	All NMES = total sugars	Natural sugars (e.g. from flour) intrinsic, added sugars NMES	Methods 1 and 3 similar
Dried fruit	Half intrinsic, half NMES	All NMES = total sugars	Intrinsic	
Chocolate confectionery	Lactose is intrinsic and milk sugars, other sugars NMES	All NMES = total sugars	All NMES (including lactose) in confectionery and biscuit categories but not ice cream	
Jams	Half fruit sugars NMES and half intrinsic. Added sugar NMES	All NMES = total sugars	Fruit sugars all intrinsic, added sugars NMES	
Ice cream	Lactose is intrinsic and milk sugars. Other sugars NMES	All NMES = total sugars	Non-dairy ice cream lactose milk and intrinsic sugars, other sugars NMES	
Yoghurts (plain)	All sugars intrinsic and milk sugars	All NMES = total sugars	All sugars intrinsic and milk sugars	Methods 1 and 3 the same
Yoghurts (sweetened)	Sucrose NMES, rest intrinsic and milk sugars	All NMES = total sugars	Added sugar NMES, rest intrinsic and milk sugars	Methods 1 and 3 the same
Canned fruit	Sugar from syrup (or juice) NMES, remainder (from fruit) half NMES and half intrinsic.	All NMES = total sugars	Sugar from syrup (or juice) NMES, sugar from fruit all intrinsic	
Stewed fruit (without sugar)	Half NMES, half intrinsic	All NMES = total sugars	All sugars NMES	
Stewed fruit (with sugar)	Added sugar NMES, fruit sugar half NMES, half intrinsic	All NMES = total sugars	Added sugar NMES, fruit sugar all NMES	
Fruit juices	All sugars NMES	All NMES = total sugars	All sugars NMES	Methods 1, 2 and 3 the same

NDNS, National Diet and Nutrition Surveys; MAFF, Ministry of Agriculture, Food and Fisheries; HNRC, Human Nutrition Research Centre, Newcastle University, UK.

NDNS surveys (Gregory *et al.* 1995, 2000; Finch *et al.* 1998). As the earlier MAFF method appears to overestimate NMES compared with the method used in the NDNS surveys, a comparison of NMES intakes from the earlier survey with the NDNS surveys is unlikely to be valid.

There is a marked difference in how the NMES values are calculated between the NDNS and HNRC methods for chocolate confectionery: the NDNS method assumes that all lactose is milk sugar and intrinsic, whereas the HNRC method includes lactose in chocolate confectionery as NMES. This difference is reflected in the higher NMES values estimated by the HNRC method than the NDNS method for chocolate confectionery (Table 2). However, although this leads to higher dietary intake values for chocolate confectionery, the mean differences are not significant within the food group (Table 4) for the population of children investigated, probably because the amount of lactose in chocolate confectionery is small compared with the added sugars content. For populations or individuals with a high chocolate consumption, however, the differences between the two methods may be more marked. Some of the points on the Bland–Altman plot where the differences between the two methods lie outside the 95 % limits of agreement (Fig. 3) are likely to be for individuals with a high chocolate intake. Within food groups, the biggest significant difference between the NDNS and HNRC methods is for confectionery, in particular chocolate confectionery (Table 2). After drinks (soft drinks and fruit juices), for which there is no difference between the NDNS and HNRC methods (Tables 2 and 4), chocolate confectionery is the biggest contributor to NMES intake in the diet of this population of young adolescents.

There were no differences in the values for NMES calculated by each of the three methods for fruit juices and soft drinks. Both the NDNS and HNRC methods effectively assume that the cellular structure of the fruit has broken down and that all sugars are extrinsic and equivalent to total sugars, so the methods are the same as the MAFF method.

It should be noted that, for recipe dishes, the NDNS method takes weight loss on cooking into account, whereas the HNRC method does not. Weight loss can be up to 40 % of the total weight of the recipe in some cases, so whereas the description of the methods may appear to be similar on paper, for example for biscuits (Table 5), the calculated NMES values for recipe dishes are different because of the different treatment of weight loss on cooking.

Relative ease and practicality of the methods

The practical application of the NDNS method required help from the additional guidelines supplied by the FSA (Appendix 1). For foods for which there was a published recipe, the guidelines were straightforward to follow. For foods with no published recipe, guidelines from the FSA were provided in some instances, for example biscuits (to calculate percentage flour from the fibre content) and jams (to estimate the proportion of fruit from fibre content). This was, however, complicated and time-consuming in practice. In other cases, the guidelines provided were vague, and it was not always clear how to estimate NMES: for example, ‘we base our estimates on 1) estimates of the proportions of the ingredients in the products and 2) the individual sugar profile and the main source of each sugar.’ In practice, it was not clear how to estimate the proportions of ingredients in a product when there was no recipe. One area that was particularly complex was processed fruit, for example stewed fruit, or fruit in pies and jams. It was necessary to know the proportions of added sugar and fruit sugars in order to carry out the calculation of 50 % of the fruit sugars as NMES. Some food composition data are available from manufacturers and food packaging, but where it is not available, the estimates may vary widely between different investigators. In these instances, the between-investigator error may outweigh the necessity for the complex approach.

On the whole, the NDNS method was a thorough, albeit complex and time-consuming, method to apply.

The MAFF method was a very simple method to apply as in most cases the NMES values were equivalent to the total sugars figure in the food tables, except for products made up with liquid milk. It was, however, not clear which products contained 'liquid milk', and further information supplied by the FSA did not resolve this issue (Appendix 1). For example, it was not clear whether 'liquid milk' included only milk consumed on its own and used by consumers, or whether it included those products made from liquid milk, such as yoghurts. The MAFF method is therefore a practically simple method that is easy to apply but should not be widely adopted as it overestimates the NMES content of most foods, except for fruit juices and confectionery.

A simpler method that combines the simplicity of the MAFF method but compensates for the over-estimation of this method could be useful in situations where access to the UK FSA database on the NMES contents of foods is not possible. Such a method could be based on, for example, total sugars minus milk sugars (lactose, including naturally occurring lactose) minus all sugars in fresh fruit (all sugars in processed fruit and fruit juices would be classified as NMES) minus a proportion of sugars in grains and flour (designated by a factor, with clear guidelines on how to estimate the flour content of foods for which there is no recipe). Further research is required to evaluate the practical feasibility and relative accuracy of such an approach.

The HNRC method was a thorough method that was more complex in practice to apply than the NDNS method. As with the NDNS method, it was relatively straightforward for foods for which a recipe was available. The method was originally based on added and natural sugars, to which fruit juices and honey were added as the method developed over the years. The further guidelines supplied were not as comprehensive or as systematic as for the NDNS method. As for the NDNS method, the calculation of values for processed fruit products was also complicated where no recipe was available, such as for tinned fruit products or fruit pies, as it was not clear how to estimate the proportions of added and naturally occurring sugars and the fruit content. Food dissection was sometimes used in this method in order to measure the fruit content of foods. This method gives very similar values to the NDNS method and continues to be used for repeated cross-sectional studies within the HNRC at Newcastle; its wider adoption is, however limited by the complexity of the method as it stands.

Conclusion

If the NMES contents of foods, and the intake and sources of NMES (and/or free sugars) by populations worldwide, are to be measured and monitored, there needs to be an accessible and unified approach to NMES estimation. Such an approach would allow comparisons between surveys and enable public health goals to be monitored. Of the three methods evaluated, the NDNS method used in the UK is the most appropriate method available for estimating dietary NMES intake, taking into account practicality and the dietary intake values obtained.

At present, the published details of the NDNS method are sparse and insufficient to allow accurate replication. Further guidelines are published here (Appendix 1), but even with these, the method is complicated to apply. It is possible to obtain the FSA NMES food tables upon direct request, but the values are currently not published in *McCance and Widdowson's The Composition of Foods* and its supplements. The publication of NMES in food tables would improve accessibility and promote a uniform approach to the measurement of NMES intakes in dietary surveys.

Acknowledgements

This research was funded by the FSA. The views expressed are the authors' own.

References

Bland JM & Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**(8476), 307–310.

Bland JM & Altman DG (1995) Comparing two methods of clinical measurement: a personal history. *Int J Epidemiol* **24**, S7–S13.

Bolton-Smith C & Woodward M (1994) Dietary composition and fat to sugar ratios in relation to obesity. *Int J Obes Relat Metab Disord* **18**, 820–828.

Buss DH, Lewis J & Smithers G (1994) Non-milk extrinsic sugars (letter). *J Hum Nutr Diet* **7**, 87.

Chan W, Brown J & Buss DH (1994) *Miscellaneous foods. Fourth Supplement to 5th Edition of McCance and Widdowson's The Composition of Foods*. Cambridge: Royal Society of Chemistry.

Department of Health (1989) *Dietary Sugars and Human Disease*. Report on Health and Social Subjects No. 36. London: HMSO.

Department of Health (1991) *Dietary Reference Values for Food Energy and Nutrients in the United Kingdom*. Report on Health and Social Subjects No. 41. London: HMSO.

Drummond S & Kirk T (1998) The effect of different types of dietary advice on body composition in a group of Scottish men. *J Hum Nutr Diet* **11**, 473–485.

Finch S, Doyle W, Lowe C, Bates CJ, Prentice A & Smithers G (1998) *National Diet and Nutrition Survey, People Aged 65 Years and Over,* vol. 1. London: HMSO.

Gregory JR, Collins DL, Davies PSW, Hughes JM & Clarke OC (1995) *National Diet and Nutrition Survey Children Aged 1.5–4.5 Years,* vol. 1. London: HMSO.

Gregory J, Lowe C, Bates CJ, Prentice A, Jackson LV & Smithers G (2000) *National Diet and Nutrition Survey Young People Aged 4 to 18 Years,* vol. 1. London: Stationery Office.

Holland B, Unwin ID & Buss DH (1988) *Cereals and Cereal Products. Third Supplement to McCance and Widdowson's The Composition of Foods*. Cambridge: Royal Society of Chemistry.

Holland B, Unwin ID & Buss DH (1989) *Milk Products and Eggs. Fourth Supplement to McCance and Widdowson's The Composition of Foods.* Cambridge: Royal Society of Chemistry.

Holland B, Unwin ID & Buss DH (1992) *Fruit and Nuts. First Supplement to 5th Edition of McCance and Widdowson's The Composition of Foods*. Cambridge: Royal Society of Chemistry.

Holland B, Welch AA, Unwin ID, Buss DH, Paul AA & Southgate DAT (1991) *McCance and Widdowson's The Composition of Foods*, 5th ed. Cambridge: Royal Society of Chemistry.
Johnson IT, Southgate DAT & Surnin JVGA (1996) Intrinsic and non-milk extrinsic sugars: does the distinction have analytical or physiological validity? *Int J Food Sci Nutr* **47**, 131–140.
Kelly SAM, Moynihan PJ, Rugg-Gunn AJ & Summerbell CS (2003) Review of methods used to estimate non-milk extrinsic sugars. *J Hum Nutr Diet* **16**, 27–38.
Ludwig DS, Peterson KE & Gortmaker SL (2001) Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective observational analysis. *Lancet* **357**, 505–508.
Mills A (1994) *The Dietary and Nutritional Survey of British Adults – Further Analysis*. London: HMSO.
Moynihan PJ & Peterson PE (2004) Diet, nutrition and the prevention of dental diseases. *Public Health Nutr* **7**, 201–226.
Rugg-Gunn AJ (2001) Preventing the preventable – the enigma of dental caries. *Br Dent J* **191**, 478–488.
Rugg-Gunn AJ, Adamson AJ, Appleton DR, Butler TJ & Hackett AF (1993) Sugars consumption by 379 11–12 year-old English children in 1990 compared with results in 1980. *J Hum Nutr Diet* **6**, 419–431.
Rugg-Gunn AJ, Fletcher ES, Matthews JNS, Hackett AF, Moynihan PS, Kelly SAM, Mathers JC & Adamson AJ (2005) Changes in consumption of sugars by English adolescents over 20 years. *Public Health Nutr* (In the Press).
Schulze MB, Manson JE, Ludwig DS, Colditz GA, Stampfer MJ, Willett WC & Hu FB (2004) Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA* **292**, 927–934.
Sheiham A (2001) Dietary effects on dental diseases. *Public Health Nutr* **4**, 569–591.
World Health Organization (1990) *Diet, Nutrition and the Prevention of Chronic Diseases: Report of a WHO Study Group*. Technical Report Series No. 797. Geneva: WHO.
World Health Organization (2003) *Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation*. Technical Report Series No. 916. Geneva: WHO.

Appendix 1: Further details of the methods for NMES estimation

1. Details of NDNS method for NMES estimation supplied by the UK Food Standards Agency

'The method for estimating non-milk extrinsic sugars used in the NDNS is that described in Buss *et al*. (1994) *Journal of Human Nutrition and Dietetics*.

Intrinsic and milk sugars include:

all sugars in fresh fruit and vegetables (including cooked and canned vegetables)
all sugars in nuts and seeds
all sugars inherent in flour and other grains
half the sugars inherent in dried, canned and stewed fruit and preserves
all lactose, whether in milk, milk products or other foods (including recipes and composite dishes)

Non-milk extrinsic sugars include:

all sugars in table sugar and honey
all sugars in fruit juice
all added sugar in manufactured products, recipes and composite dishes
half the sugars inherent in dried, canned and stewed fruit and preserves

For processed foods we estimate the proportions of naturally occurring sugars, added sugars and milk sugar. We base our estimates on:

i) estimates of the proportions of ingredients in the product
ii) the individual sugar profile and the main source of each sugar

To give some examples how we estimate NMES content of different types of processed foods:

Breakfast cereals	Not containing fruit – assume sucrose is extrinsic and other sugars intrinsic Containing fruit – estimate proportion of sugars coming from fruit and take as half intrinsic and half extrinsic.
Biscuits	Estimate % flour from fibre content and so sugars coming from flour. Take sugars from flour as intrinsic and rest as extrinsic.
Fruit biscuits	Estimate proportion of sugars from fruit and take as half intrinsic and half extrinsic, then as above.
Chocolate biscuits	Take lactose as intrinsic and milk sugar, then as above.
Bread	All intrinsic
Chocolate	Take lactose as intrinsic and milk, rest as extrinsic
Jam	Estimate proportion of fruit (from fibre content). Estimate sugars from fruit – take half extrinsic and half intrinsic. Take rest of sugar as extrinsic.
Canned fruit with syrup	Estimate proportion of syrup and sugar content of syrup. Take sugar from syrup as extrinsic; remainder (from fruit) as half extrinsic and half intrinsic.
Ice-cream	Take lactose as intrinsic and milk and rest as extrinsic.
Yoghurt: plain yoghurt	Take as all intrinsic and milk sugars
Sweetened yoghurt	Take sucrose as extrinsic and rest as intrinsic and milk.

The nutrient databank for the NDNS incorporates a recipe calculation program which is used to calculate the proportion of NMES (and other nutrients) in recipe dishes from the ingredients so we do not need to estimate these directly.'

After receiving the above information, further clarification of the method was also requested from the FSA on whether weight loss in recipe dishes is taken into account in the NDNS method, and weight loss is indeed taken into account when estimating the NMES content of recipe dishes.

Even with the information supplied as above, there were in practice, when calculating NMES values with the fifth edition food tables, a number of factors that were still open to individual interpretation:

1.1 In recipe dishes that incorporate eggs, the weight of an egg was taken as 50 g (standard portion size).

1.2 In recipe dishes in which weight was lost on cooking/heating, weight loss was taken into account by calculating the NMES content per total weight of the recipe after adjusting the total weight of the recipe for weight loss.

1.3 For some foods, there is a recipe in *McCance and Widdowson's The Composition of Foods* and also alternative guidelines on how to calculate NMES. For some biscuits, for example, there is a recipe, but the NMES content can also be estimated by following the general guidelines by estimating sugars in flour from the fibre content. It was not clear which route should be followed in such instances. If a recipe was available, NMES were determined from the recipe compositions.

1.4 For foods for which no recipe was available in McCance and Widdowson, it was not clear where details of the food composition should be obtained from. For a product like pizza, for example, different manufacturers' products have different compositions. In general, this information was obtained from a representative manufacturer's details or product packaging.

1.5 For jams and products containing jam filling, the type of jam, such as strawberry, is often not specified. In these cases, it was assumed that the jam was strawberry jam, but slightly different values would be obtained if another type of jam were to be used (because the fibre content is different and the proportion of fruit in jam is based on fibre content).

1.6 The method for jam was based on an estimation of fibre content, but the method (Southgate or Englyst) was not specified. In these cases, the average of the two was used. In those cases in which a value was given for only one fibre content method, that figure (either Englyst or Southgate) was used.

1.7 For soups and sauces, no guidelines were provided by the FSA. It was assumed that all sugars were extrinsic except for lactose in cream soups. This assumption was made because the general guidelines from the FSA specified that 'intrinsic and milk sugars include: all lactose, whether in milk, milk products or other foods (including recipes and composite dishes).'

1.8 Tomatoes were treated as fruit; tomato juice, for example, was treated as fruit juice. Sugars from tomatoes in tomato sauce and tomato purée were treated as half intrinsic and half NMES, i.e. treated the same as canned fruit. The treatment of sauces and purées was not specified by the FSA, and this case illustrates the difficulties that arise unless clear guidelines are provided.

1.9 This project only covers NMES values for foods in the fifth edition of *McCance and Widdowson's The Composition of Foods*. Lactose values, where applicable, were taken from the supplements to this book – cereals and cereal products (Holland *et al.* 1988), milk and milk products (Holland *et al.* 1989), fruit and nuts (Holland *et al.* 1992) and miscellaneous foods (Chan *et al.* 1994) – as the contents of individual sugars are not listed in the fifth edition. In some cases, however, the value for total sugars in the fifth edition is different from that in the supplements. Where it seemed appropriate, the lactose value was scaled up or down in proportion.

2. Details of the MAFF method supplied by the FSA (formerly MAFF)

The original print of the report in which this method was published stated 'intakes estimated from total sugars by deducting the sugars from liquid cow's milk, *fruit and fruit products (excluding fruit juice)*', but the FSA have confirmed (personal communication) that the method was altered for later prints and did not deduct the sugars in fruit and fruit products, the actual method used being as follows: 'an estimate of NMES intake was made by subtracting sugars from liquid milk from total sugars (NMES = total sugars minus sugars from liquid, whole, semi-skimmed and skimmed cows milk).'

Further clarification was sought from the FSA over which foods contained 'liquid milk' and whether sugars from liquid milk would include sugars from milk in recipe dishes, for example pancakes. The response was that sugars from milk in recipe dishes should not be included as 'liquid milk'.

Even with the above further information, it was not, however, clear which foods contained 'liquid milk'. For this study, the following assumptions were made:

2.1 The following products are described in the fifth edition as being made up with milk: porridge, custard (made with milk), instant dessert powder, milk pudding, Bournvita powder, build-up powder, cocoa powder, drinking chocolate powder, Horlicks, milk shake powder, bread, cheese, onion and white sauce mixes. In these cases, the total sugars value for the appropriate form of liquid milk (i.e. whole, semi-skimmed or skimmed) were subtracted from the total sugars value for the foodstuff (fifth edition value).

2.2 This meant that in all other cases when this method was applied: NMES = total sugars. Sugars from milk were not subtracted from cheese, yoghurt, cream, ice cream, chocolate, soups or other recipe dishes as these were not considered to be in the form of 'liquid milk'. Even yoghurt and cream do not fit the description of 'liquid milk' because the description supplied by the FSA specifies 'liquid milk' as 'whole, semi-skimmed and skimmed cows milk' and does not include the milk in recipe dishes that incorporate milk.

2.3 Weight loss in recipe dishes did not apply to this method as in all recipe dishes, NMES = total sugars.

3. Details of the HNRC method.

3.1.1 In bread, all sugars = intrinsic and milk.

3.1.2 In breakfast cereals, natural sugar = intrinsic and milk.

3.1.3 In biscuits, natural sugar = intrinsic and milk.

3.1.4 Dried fruit sugar = intrinsic and milk.

3.1.5 Baked goods with milk component – lactose and natural sugars = intrinsic and milk.

3.1.6 Non-dairy ice cream lactose = intrinsic and milk.

3.1.7 Use the lactose values in *McCance and Widdowson's The Composition of Foods* Milk and Egg Products food table supplements where possible, for example for ice creams, choc ice, etc.

3.1.8 Sugars in pizza, curry, lasagne, casserole, stews = intrinsic.

3.1.9 Puréed foods = NMES (except mashed potato).

3.1.10 Purées and sauces unless milk based = NMES. (If milk based, lactose = intrinsic and milk sugars).

3.1.11 Soups – look at lactose for cream soups (lactose intrinsic and milk, other sugars NMES).

3.1.12 Baked beans, assume all sugars = NMES.

3.1.13 Chocolate (including milk chocolate) = all sugars NMES. (In confectionery and biscuit categories but not ice cream categories.)

3.1.14 Chocolate in cakes = NMES.

3.1.15 Apple chutney is based on values for tomato chutney. As tomato chutney = 12.8 % intrinsic and 32 % NMES, apple chutney was calculated as 12·8 % intrinsic and 38·3 % NMES.

3.1.16 All stewed fruit sugars = NMES.

3.1.17 Fruit sugars in pie fillings, jams = intrinsic.

3.1.18 Sugars from nuts (including ground/puréed nuts) = intrinsic.

3.1.19 Fruit juices – all sugars = NMES.

3.1.20 Weight loss in recipe dishes is *not* taken into account in the HNRC method. For recipe dishes, NMES content (g/100 g) was determined on the recipe as published in *McCance and Widdowson's The Composition of Foods* without subtracting any losses resulting from heating or cooking.

This method was originally based on an added sugars method first developed in 1980, and the method has developed over time. The following additional information was obtained or assumptions were made in order to apply the method:

3.2 Many of the NMES values calculated by this method were originally calculated for the *McCance and Widdowson's The Composition of Foods* food table supplements rather than the fifth edition of the food tables. In some cases, the total sugar value differs between the fifth edition and the supplements. In these cases, it has been assumed that the difference in total sugar value is caused by differences in added extrinsic sugar; with breakfast cereals, for example, the difference in sugar content often results from changes in the level of sugar added by the manufacturers.

3.3 Even with the guidelines previously outlined, there were a number of areas in which assumptions had to be made. As with the NDNS method, this mainly applied to products where there was no recipe in *McCance and Widdowson's The Composition of Foods*. If no recipe was available, this method was based on manufacturers' food composition data or, if these were unavailable, food dissection, for example to estimate proportion of raisins in a product.

3.4 Natural sugars were estimated to be 0·4 g/100 g in breakfast cereals (without fruit) and cakes (without fruit or jam).

3.5 Tomato sauce was treated as a puréed food.