Assessing caffeine intake in the United Kingdom diet

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1. Introduction

Caffeine, the common name for the chemical compound 1,3,7-trimethylxanthine, is the most widely consumed methylxanthine alkaloid group (Riksen, Smits, & Rongen, 2011). It occurs naturally in many plant species but is mainly derived from cocoa beans (Theobroma cacao), coffee beans (Coffea Arabica and Coffea robusta), kola nuts (Cola acuminata) and tea leaves (Camellia sinensis). Synthetic forms of caffeine are used to enhance a variety of food and drink products (Finnegan, 2003) as well as dietary supplements and medication (Andrews et al., 2007). A recent review of the functionality of caffeine suggests it is one of the most widely consumed food ingredients worldwide with tea and coffee being the most prominent sources in the diet (Heckman, Weil, & Gonzalez de Mejia, 2010), of which coffee is the second most commonly consumed beverage worldwide after water (Butt & Sultan, 2011).

1.1. Health effects of caffeine consumption

Artificial and natural caffeine sources have similar physiological effects on the human body (Heckman et al., 2010) with a relatively short half-life of 5 h (Charles et al., 2008) which can lead to acute and negative physiological symptoms including indigestion, anxiety, headache, insomnia (Shirlow, Berry, & Stokes, 1988; Shirlow & Mathers, 1985) and diuresis particularly in those not accustomed to caffeine (Maughan & Griffin, 2003). Whilst it has long been purported these effects are due to caffeine’s rapid absorption into the gastrointestinal tract and central nervous system, where it is known to stimulate gastric acid secretion, elevate heart rate and act as a smooth muscle relaxant (Graham, 1978), more recent research has suggested caffeine consumption and even the expectation of having consumed caffeine can improve attention and psychomotor speed, suggesting a desirable placebo effect on mood and performance (Dawkins, Shahzad, Ahmed, & Edmonds, 2011).

Associations have been suggested between caffeine intake and health status, particularly amongst females. Prolonged excessive caffeine intake and delayed conception has not been supported (Hatch et al., 2012; Peck, Leviton, & Cowan, 2010), however there is evidence to suggest an association between caffeine intake during pregnancy and an increased risk of fetal growth restriction, late miscarriage and stillbirth (CARE Study Group, 2008; Greenwood et al., 2010). This effect is believed to be due to a delay in caffeine excretion during pregnancy which allows higher serum caffeine levels to cross the placenta. The impact of caffeine consumption on osteoporosis risk is less clear, with research suggesting reduced bone mineral density may be due to interactions of smoking, age, gender and alcohol intake as opposed to caffeine ingestion (Cooper et al., 1992) and positive interactions suggested from the intake of polyphenols which are often present in caffeinated beverages (Dew, Day, & Morgan, 2007). However, an increased risk of fracture at specific sites has been reported among post-menopausal women consuming self-reported intakes >300 mg/d caffeine from coffee, when calcium intake is also low (Hallstrom, Wolk, Glynn, & Michelson, 2006; Rapuri, Gallagher, Kinyamu, & Ryschon, 2001). Conversely, positive health outcomes relating to caffeine intake have been reported in studies assessing coffee consumption, including inverse associations between regular caffeine consumption and risk of developing type 2 diabetes (Du, Melchert, Knopf, Braemer-Hauth, & Pabel, 2007; van Dam, Willett, Manson, & Hu, 2006), Parkinson’s Disease (Costa, Lunet, Santos, Santos, &
Vaz-Carneiro, 2010; Liu et al., 2012) and gliomas (Michaud et al., 2010), as well as a dose-related decreased prevalence of non-melanoma skin cancer in Caucasian women (Abel et al., 2007).

1.2. Recommended caffeine intake

For adults, moderate caffeine intakes of approximately 300 mg/d are well tolerated, with some evidence of potential health benefits (Higdon & Frei, 2006), and although there is no dietary recommendation for caffeine intake in the UK, guidance for healthy adults is to observe this moderate level of intake, with sensitive individuals and children advised to consider lower intake. In 2008, the UK Food Standards Agency recommended that caffeine intake in pregnant women should not exceed 200 mg/d (Food Standards Agency, 2008) due to new evidence around the associated health risks to the unborn child as we have already mentioned (CARE Study Group, 2008). Canada is one of the few countries worldwide to have set population recommendations for caffeine intake and includes specific guidance for children at 45 mg/d for 4–6 y, 62.5 mg/d for 7–9 y and 85 mg/d for 10–12 y (Health Canada, 2010). Fatal doses of caffeine in adults are estimated at upwards of 170 mg/kg body weight (Graham, 1978) and there have been few reported cases of death due to caffeine overdose (Nawrot et al., 2003).

Since 2002, European Union rulings for caffeine labelling require a beverage containing caffeine, in excess of 150 mg/l, and intended for consumption without modification or after reconstitution, to be clearly labelled as ‘High caffeine content’ (European Community, 2002). This directive covers most caffeinated energy drinks, how-ever, tea and coffee based beverages are exempt so long as the product is clearly labelled as containing tea or coffee.

There is a lack of research to estimate total daily caffeine intake in the UK population (Derbyshire & Abdula, 2008). Data for the caffeine content of a variety of food, drinks and dietary supplements are available in other countries, specifically the USDA National Nutrient Database for Standard Reference (SR) release 23 (USDA, 2008) and from numerous individual companies, including Coca-Cola and Starbucks, but is not currently included in UK food composition tables. We compiled a database of caffeine data, applicable to UK foods and drinks, to estimate total caffeine intake in a nationally representative population sample from the National Diet and Nutrition Survey (NDNS) 2008–10.

2. Method

2.1. Study population and estimation of caffeine intakes

We examined the individual food intakes of core sample participants in the NDNS rolling programme years 1 and 2 (2008–9 and 2009–10, n = 2126), which is a nationally representative sample of free-living UK inhabitants aged 1.5 years upwards. Pregnant women are not eligible to take part in NDNS. Only participants who had consumed food or drink containing caffeine during the recording period were included in analyses (n = 208), we excluded all non-caffeine consumers from this study (n = 118). Food consumption in NDNS is measured using a 4 day weighed food diary and dietary intakes were calculated based on the food composition data held in the Nutrient Databank (Smithers, 1993), which at the time of this project contained 5249 food codes. Further details regarding the NDNS sampling procedure, dietary assessment component and weightings are available elsewhere (Whitten et al., 2011).

All food codes recorded during NDNS 2008–10 were examined, and we identified those within 35 food groups that potentially contained caffeine. Food codes that could not be identified clearly from their description, as definitive flavours or varieties, were removed at this stage. Caffeine content of each identified food code (n = 208) was calculated as mg/100 g or mg/100 ml.

2.2. Determination of caffeine values and data sources

A literature review of published caffeine data was conducted, using PubMed and Scopus, together with a review of analytical reports and manufacturer’s data, with priority given to data collected in the UK in order to standardise against the products that would have been consumed by NDNS respondents (Table 1). Discrete caffeine containing food codes such as tea, coffee, cocoa powder, chocolate and cola were assigned a caffeine value from data in a single literature source that provided the most comparability to the food code description. In these situations we chose to assign the same value as stated in the literature, on the acceptance the value was already derived as a mean of multiple sampling. Where analytical data could not be directly mapped against a food code a calculation was made based on percentage content of the main caffeine containing ingredient. For example, biscuits with a coating of 10% milk chocolate were assigned a caffeine value calculated from 10% of the total for the milk chocolate food code. All food codes were subject to a secondary data source check to ensure reasonableness of the caffeine data being used. The majority of data checks were carried out using the USDA National Nutrient Database SR23 (USDA, 2011), which was particularly useful when reviewing branded confectionery products and soft drinks as there were often identical products available as in the UK market. An extract of the caffeine content of selected food and drinks items as used in this study are shown in Table 2.

Food intake frequencies of each caffeine-consumption occasion were used to estimate mean total caffeine intake (TCI, mg/d), based on weights and volumes recorded by the respondent in the food diary. A total of 33078 caffeine-consumption occasions were included in the analysis, which included all consumption of caffeine >0 mg, from any food, drink or dietary supplement. We examined caffeine consumers only in this study and as such all data represent estimated caffeine intakes for consumers only. No estimation was made for potential caffeine intakes from prescription or over-the-counter medications as these are not recorded within the food diary. Data for caffeine intake from food, drink and supplement sources were computed as mean total caffeine intake (TCI, mg/d), mean caffeine intake (CI, mg) per caffeine occasion (CO) and as contributed from coffee, tea, energy and soft drinks. Age and sex groups reported are aligned with the NDNS reporting groups. Comparisons of mean TCI between age and sex groups were made using independent t-tests, with p < 0.05 considered significant. Data were analysed using PASW Statistics Data Editor Version 18 (SPSS Inc.).

3. Results

3.1. Total caffeine intake (TCI)

The mean CI/CO across all the age and sex groups, ranged from 6–37 mg, lowest in 1.5–3y and highest in men 19–64 y (Table 3). Children and young people 1.5–18 y reported mean CI/CO of 6–24 mg and adults 19+ y 32–37 mg. Mean TCI was higher in males than females in sex specific groups from age 4+ y and increased with age; boys and girls 4–10 y had mean TCI of 13 mg/d and 12 mg/d respectively, boys and girls 11–18 y 46 mg/d and 44 mg/d, men and women 19–64 y 130 mg/d and 122 mg/d, and men and women 65+ y 143 mg/d and 131 mg/d (p < 0.05). A total of
3.2. Caffeine intake from caffeinated beverages

We compared mean CI from tea, coffee, and energy and soft drinks, in consumers only (Table 4). For all caffeine consumers caffeine contributed more caffeine (49.5 mg/d) than tea (36.2 mg/d) and energy and soft drinks (34.5 mg/d). Coffee contributed significantly greater amounts of caffeine than tea in men 19–64 y (51.7 mg/d; 38.7 mg/d), men 65+ y (52.0 mg/d; 40.4 mg/d) and women 19–64 y (49.5 mg/d; 37.7 mg/d), as well as when compared to energy and soft drinks in women 19–64 y (49.5 mg/d; 32.8 mg/d) and higher in the adult age groups with men consuming more caffeine from coffee than women (women 19–64 y 49.5 mg/d, women 65+ y 49.5 mg/d, men 19–64 y 51.7 mg/d, and men 65+ y 52.0 mg/d). Caffeine intake from tea and energy and soft drinks were significantly different between girls 4–10 y (27.5 mg/d; 22.1 mg/d), boys 4–10 y (27.4 mg/d; 27.8 mg/d), boys 11–18 y (35.1 mg/d; 40.8 mg/d), and women 19–64 y (37.7 mg/d; 32.8 mg/d) (p < 0.05).

The most concentrated single source of CI for consumers, as consumed, in the combined age groups was Rockstar energy drink which contributed 169 mg caffeine per mean serving (33.7 mg/100 ml). The second food code with the greatest caffeine contribution was coffee, strong fresh infusion with 140 mg caffeine per mean serving size (88.3 mg/100 ml). Although coffee, instant powder or granules contains the greatest amount of caffeine per 100 g (3399.6 mg/100 g), the mean CI/serving is only 40 mg due to the small quantity used when preparing this beverage.

4. Discussion

Caffeine is found in numerous foods and beverages that are commonly consumed in the UK, but it has been difficult to produce accurate estimates of intake for the UK population as caffeine is not included in the UK food composition tables. The aim of this study was to populate the food composition database used in the UK NDNS to produce an estimate of recent caffeine intake for the UK population. We estimated mean TCI from dietary sources for males and females aged 1.5 y upwards, using food intake data from the NDNS 2008–10. This enabled us to compare intakes with the moderate caffeine intake guidance and to make a broad comparison with caffeine intake in other countries.

In our analysis of caffeine consumers mean TCI in adults ranged from 122–143 mg/d, with 4.1% men and 3.8% women 19+ y displaying estimated intakes in excess of 300 mg/d. There are currently no UK recommended guidelines for maximum caffeine intakes in children, however mean TCI of children in our sample were below the age recommendations for Canadian children, which are 45 mg/d for 4–6 y up to 85 mg/d for 10–12 y. Some energy and soft drinks can contain very high concentrations of caffeine, which are 45 mg/d for 4–6 y up to 85 mg/d for 10–12 y. Some energy and soft drinks can contain very high concentrations of caffeine, which are 45 mg/d for 4–6 y up to 85 mg/d for 10–12 y.

Table 2

<table>
<thead>
<tr>
<th>Food code description</th>
<th>Caffeine content mg/100 g or ml (data source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tea, weak infusion</td>
<td>16.5 (Food Standards Agency, 2004a; Food Standards Agency, 2004b)</td>
</tr>
<tr>
<td>Tea, strong infusion</td>
<td>22.0 (Food Standards Agency, 2004a; Food Standards Agency, 2004b)</td>
</tr>
<tr>
<td>Tea, green, infusion</td>
<td>15.1 (Yamada et al., 2009)</td>
</tr>
<tr>
<td>Coffee, instant powder or granules</td>
<td>3399.6 (CARE Study Group, 2008)</td>
</tr>
<tr>
<td>Coffee, fresh weak infusion</td>
<td>44.5 (Food Standards Agency, 2004a; Food Standards Agency, 2004b)</td>
</tr>
<tr>
<td>Vending machine coffee and whitener</td>
<td>31.4 (Food Standards Agency, 2004a; Food Standards Agency, 2004b)</td>
</tr>
<tr>
<td>Milk chocolate, no additions</td>
<td>16.8 (MAFF, 1998)</td>
</tr>
<tr>
<td>Dark chocolate (plain), no additions</td>
<td>52.5 (MAFF, 1998)</td>
</tr>
<tr>
<td>Nestle KitKat</td>
<td>11.1 (calculated from 66% milk chocolate as stated in ingredients)</td>
</tr>
<tr>
<td>Cola, not canned, low calorie</td>
<td>11.4 (MAFF, 1998)</td>
</tr>
<tr>
<td>Irn Bru carbonated drink</td>
<td>12.0 (Manufacturers data)</td>
</tr>
<tr>
<td>Lucozade Original Energy</td>
<td>30.0 (Manufacturers data)</td>
</tr>
<tr>
<td>Red Bull Stimulation Sugar Free</td>
<td>8.7 (Andrews et al., 2007)</td>
</tr>
<tr>
<td>Green tea extract capsules</td>
<td>30.0 (Manufacturers data)</td>
</tr>
</tbody>
</table>

400 samples of teas and coffees prepared by consumers were collected from family homes, workplaces or purchased in retail settings from 10 areas across the UK. Caffeine values for 29 instant coffees were below the age recommendations for Canadian children, which are 45 mg/d for 4–6 y up to 85 mg/d for 10–12 y. Some energy and soft drinks can contain very high concentrations of caffeine, which are 45 mg/d for 4–6 y up to 85 mg/d for 10–12 y.
Mean TCI NS between men and women 19+, girls and boys 11–18 and girls and boys 4–10. (2011) analysed caffeine intake for the French population in a pro-
razzi, Touillaud, Boutron-Ruault, Clavel-Chapelon, and Romieu 
data. of 300 mg/d, which is twice that reported in this analysis of NDNS (2008) reported 18% of participants (Scott, Chakraborty, & Marks, 1989 ). Derbyshire and Abdula 
call, increased with age, for people 2–54 y. Conversely in that 
study, men and women 35–64 y consumed the most caffeine, com-
pared to the over 65 y group in our sample and mean caffeine 
intakes were also higher at 193 mg/d (Frary et al., 2005). Faghe-
caffeine and represent a concentrated source of caffeine in the diet, 
particularly among young people <18y. We found a greater num-
ber of boys and girls 4–18 y were consumers of these beverages 
than tea or coffee consumers combined. In future studies it would 
be beneficial to categorise energy drinks and soft drinks separately, 
however due to small sample numbers in the younger age groups it 
was not possible to do so in this analysis.

TCIs within our population group are similar to those cited in 
recent small-scale UK based studies of 92–146 mg/d (Khokhar & 
Magnusdottir, 2002) and 174 mg/d (Derbyshire & Abdula, 2008) 
amongst consumers, but adult male intakes are less than the pop-
ulation estimates cited as 239 mg/d (COT, 2001) and 359 mg/d 
(Scott, Chakraborty, & Marks, 1989). Derbyshire and Abdula 
(2008) reported 18% of participants (n = 70) consumed in excess 
of 300 mg/d, which is twice that reported in this analysis of NDNS 
data.

Our data is comparable to that of a large sample (n = 15,716) 
from the 1994–96 and 1998 Continuing Survey of Food Intakes 
by Individuals in the USA reported by Frary, Johnson, and Wang 
(2005), where caffeine intake, assessed by multiple pass 24 h re-
call, increased with age, for people 2–54 y. Conversely in that 
study, men and women 35–64 y consumed the most caffeine, com-
pared to the over 65 y group in our sample and mean caffeine 
intakes were also higher at 193 mg/d (Frary et al., 2005). Faghe-
razzi, Touillaud, Boutron-Ruault, Clavel-Chapelon, and Romieu 
(2011) analysed caffeine intake for the French population in a pro-
spective cohort study from self-reported food frequency question-
naires collected between 1993 and 1995 and reported median 
intakes of 164 mg/d. Caffeine intake in Japan was assessed from re-
peated 4d weighed food diaries, at 256.2 mg/d in males and 
268.3 mg/d in females, with the main dietary sources of caffeine 
being Japanese and Chinese teas and coffee products (Yamada 
et al., 2009). We may deduce from these studies that there is wide 
international variation in caffeine intakes reported between coun-
tries; however there were also differences in the dietary assess-
ment methods and sampling criteria, compared to that used in 
the UK NDNS, which may account for some of the apparent varia-
tion in caffeine intake.

This study has provided a preliminary estimate of caffeine in-
takes for the UK population and there are some limitations to the 
alalysis that should be taken into consideration when reviewing the 
data. The dietary assessment method used in NDNS is an un-
weighed food diary and therefore standardised portion sizes are 
sometimes required, as are standard measures for beverage 
strengths where enough detail has not been recorded by the 
respondent. For instance the default measurement for instant cof-
fee in NDNS is set at 1 g, based on a level teaspoon (Food Standards 
Agency, 2002), which may be an underestimate of strength partic-
ularly when consuming larger volumes. Similarly, the default 
strength for tea infusions is standardised to weak/medium, which 
is the most commonly reported strength for this beverage, so we 
may also be underestimating caffeine in this beverage. This study

Table 3
Caffeine intake (CI, mg), of caffeine consumers only, in NDNS 2008–10, by age (y) and sex group.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>All 1.5–3</th>
<th>Boys 4–10</th>
<th>Boys 11–18</th>
<th>Men 19–64</th>
<th>Men 65+</th>
<th>Girls 4–10</th>
<th>Girls 11–18</th>
<th>Women 19–64</th>
<th>Women 65+</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffeine consumers (unweighted n)</td>
<td>158</td>
<td>197</td>
<td>228</td>
<td>341</td>
<td>93</td>
<td>195</td>
<td>212</td>
<td>456</td>
<td>128</td>
<td>808</td>
</tr>
<tr>
<td>Mean TCI (mg/d)</td>
<td>6 ± 11</td>
<td>13a ± 18</td>
<td>46b ± 43</td>
<td>130c ± 88</td>
<td>143c ± 94</td>
<td>12a ± 13</td>
<td>44b ± 45</td>
<td>122c ± 87</td>
<td>131c ± 88</td>
<td>79 ± 84</td>
</tr>
<tr>
<td>Individuals consuming &gt; 300 mg/d</td>
<td>0 0 0</td>
<td>3.8/13</td>
<td>5.4/5</td>
<td>0 0</td>
<td>3.7/17</td>
<td>3.9/5</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mean CI/CO (mg)</td>
<td>6 10</td>
<td>24</td>
<td>37</td>
<td>34</td>
<td>10</td>
<td>23</td>
<td>32</td>
<td>34</td>
<td>25</td>
<td>–</td>
</tr>
<tr>
<td>Mean caffeine occasions/day (n)</td>
<td>1.4 1.6 2.1</td>
<td>3.7 4.2</td>
<td>1.7 2.2</td>
<td>3.8 3.9</td>
<td>2.8</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Mean TCI NS between men and women 19+, girls and boys 11–18 and boys 4–10.

Table 4
Mean caffeine intake (mg/d, SD) contributed from caffeine-containing beverages (consumers only), in NDNS 2008–10, by age (y) and sex group.

<table>
<thead>
<tr>
<th>Beverage type</th>
<th>All 1.5–3</th>
<th>Boys 4–10</th>
<th>Boys 11–18</th>
<th>Men 19–64</th>
<th>Men 65+</th>
<th>Girls 4–10</th>
<th>Girls 11–18</th>
<th>Women 19–64</th>
<th>Women 65+</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tea (mg/d) consumers (unweighted n)</td>
<td>19.6 ± 8.5 (40)</td>
<td>27.4 ± 7.6 (39)</td>
<td>35.1 ± 8.1 (91)</td>
<td>38.7 ± 3.3 (240)</td>
<td>40.4 ± 14.4 (76)</td>
<td>27.5 ± 5.9 (51)</td>
<td>35.4 ± 8.7 (90)</td>
<td>37.7 ± 8.4 (321)</td>
<td>38.3 ± 10.5 (97)</td>
<td>36.2 ± 11.3 (1045)</td>
</tr>
<tr>
<td>Coffee (mg/d) consumers (unweighted n)</td>
<td>0 (0)</td>
<td>34.0 ± 0 (3)</td>
<td>37.4 ± 14.9 (27)</td>
<td>51.7 ± 30.9 (210)</td>
<td>52.0 ± 39.1 (67)</td>
<td>3.4 (1)</td>
<td>40.9 ± 13.8 (27)</td>
<td>49.5 ± 35.7 (232)</td>
<td>49.5 ± 26.2 (74)</td>
<td>49.5 ± 32.3 (641)</td>
</tr>
<tr>
<td>Energy &amp; soft drinks* (mg/d) consumers (unweighted n)</td>
<td>16.2 ± 11.2 (20)</td>
<td>27.8 ± 14.7 (66)</td>
<td>40.8 ± 24.0 (155)</td>
<td>41.8 ± 23.8 (140)</td>
<td>24.3 ± 18.4 (15)</td>
<td>22.1 ± 14.4 (71)</td>
<td>36.0 ± 21.6 (145)</td>
<td>32.8 ± 17.2 (164)</td>
<td>26.2 ± 16.7 (15)</td>
<td>34.5 ± 21.4 (791)</td>
</tr>
</tbody>
</table>

*Soft drinks includes carbonated caffeinated beverages such as colas and peppers.

**Mean caffeine intake values sharing the same letters are significantly different (p < 0.05).**

Total participant numbers (unweighted n) in NDNS 2008–10 (including non-caffeine consumers) were: all 1.5–3 y n = 219, boys 4–10 y n = 210, boys 11–18 y n = 238, men 19–64 y n = 346, men 65+ y n = 96, girls 4–10 y n = 213, girls 11–18 y n = 215, women 19–64 y n = 461, women 65+ y n = 128.

NB cocoa-based beverages are not reported as consumption of cocoa powder used as a baking ingredient could not be determined from beverage use.
collated caffeine values from a variety of sources and although analytical data was the preferred measure we have also needed to utilise data collected outside the UK. It would be preferable to include data from UK only analytical sources to ensure comparison to the foods and beverages being consumed by our sample group and future updates to the database will take this into consideration. A recent study by Crozier, Stalmach, Lean, and Crozier (2011) found a 6-fold difference in caffeine between espresso coffees \( (n = 20) \) purchased from different retail outlets when analysed using HPLC, which further reinforces the necessity for accurate and reliable data on caffeine as well as demonstrates the variation in caffeine that can occur with beverage preparation methods.

5. Conclusions

This examination of caffeine consumers in the UK suggests that more than 95% of adults and most children and young people consume caffeine within the suggested moderate limits. However, the growing popularity of stronger espresso coffee beverages, and caffeinated energy and sports drinks, may preface a rise in caffeine consumption particularly within certain population groups. The addition of caffeine content of food and drinks to the UK food composition databases will allow more detailed study of population-level exposure to caffeine, trends over time and through further application in prospective cohorts and intervention studies potentially enable further examination of the health effects of caffeine consumption.

Acknowledgements

This work was supported by the UK Medical Research Council, programme number MC US A090 0056-04.

References


