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Brief Communication

Energy density predicts preferences for fruit and vegetables in 4-year-old children

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Animals ingest food primarily because it provides metabolisable energy. Mechanisms exist which allow food choice to be adjusted to meet needs for essential nutrients, but these are often achieved by, or subordinate to, meeting energy needs (Berthoud & Seeley, 2000).

For adaptive dietary selection, the animal must learn to anticipate the impact of a food on its internal state (Booth, 1985; Kyriazakis, Tolkamp, & Emmans, 1999). In controlled circumstances, flavour preferences can be acquired by association with postingestive energy from impressively small concentrations of nutrient (Ackroff & Sclafani, 1994).

Children's learning also appears to be quite sensitive to differences in energy intake. For example, Birch and colleagues have shown that 2–5-year-old children develop preferences (over 8–12 exposures) for novel flavours paired with the more energy-dense of two yoghurts or drinks, where the difference in energy ranged from 110 to 160 kcal per serving (Birch, 1999). We believe that learning about this property of foods could be a key influence on the development of young children's food preferences.

Fundamental influences on children's likes and dislikes are more likely to be detected when the preferences are averaged over large samples, so that idiosyncratic variation is minimised. Our data from 416 4–5-year-old children from the Twins Early Development Study provides such a sample (Wardle, Sanderson, Gibson, & Rapoport, 2001). Mothers completed a questionnaire of their children's likes and dislikes for 94 common foods (some items combined similar foods, e.g. marrow and courgette).

A core interest of ours is in barriers to increasing consumption of fruit and vegetables, because of their protective effects against cancer and cardiovascular disease (Joshipura et al., 2001; La Vecchia & Tavani, 1998). Consumption remains well below recommended levels among adults (Li et al., 2000) and children (Gregory et al., 2000). One such barrier might include the relatively low energy value of many fruits and vegetables (Gibson & Wardle, 2001). We reasoned that these two food groups could be sensitive to any effects of energy density on average preferences because (a) cultural influences on liking for them may be quite homogeneous, and (b) there is a tenfold variation in energy density between, for example, an energy-poor vegetable such as marrow (0.4 kJ/g) and a relatively energy-rich fruit such as the banana (4 kJ/g). Moreover, in a recent study of spider monkeys *Ateles geoffroyi*, preference rank of fruit and vegetables in the monkeys' regular captive diet correlated 0.79 with energy value, whereas neither macronutrients nor dietary sugars significantly predicted preference (Laska, Salazar, & Luna, 2000).

Our hypothesis was that young children would show a greater preference for more energy-dense fruit and vegetables. This was tested by correlating (Pearson's r) energy density (kJ/g) for each fruit or vegetable item (Holland et al., 1992) with their average preference scores (-2 = 'dislikes a lot' to $+2$ = 'likes a lot'). Where questionnaire items consisted of more than one fruit or vegetable, the averaged energy density was used. Values for cooked vegetables (without oil) were used, where this is the typical British serving method. Fried or roasted potatoes were excluded.

Preference scores were included for 21 fruit and vegetable items. The proportion of children having tried these fruits and vegetables ranged from 54.8 to 100%. Avocado was excluded, as only 28% of the sample had tried this fruit, and it is unique among fruits and vegetables in having more than 90% of energy as fat.

Fruit and vegetable mean preference scores were significantly positively correlated with energy density, $r = 0.65$, $N = 21$, $p < 0.001$ (Fig. 1: $r^2 = 0.42$; all p values one-tailed). When fruit were considered separately from vegetables, energy density still predicted preference: for fruit, $r = 0.67$, $N = 8$, $p < 0.05$; for vegetables, $r = 0.55$, $N = 13$, $p = 0.025$. When the proportion of children having

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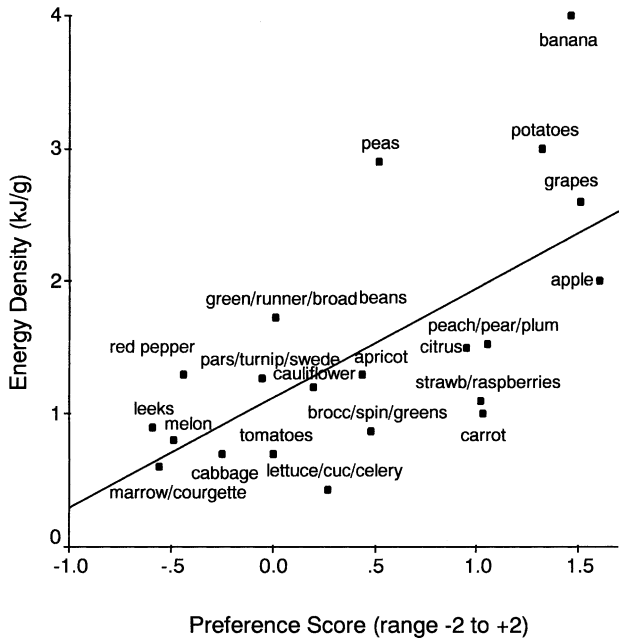

Fig. 1. Energy density versus children's preference scores for fruit and vegetables. Linear regression explained 42% of the variance (SPSS v 10.1). Pearson's $r = 0.65$. Preference scores were averaged from mothers' ratings for their 4–5 year-old children ($N = 228–416$).

tried each fruit or vegetable was controlled for, the overall correlation between energy density and preferences for fruit and vegetables remained significant, partial correlation $r(18) = 0.58$, $p < 0.005$.

It may be argued that variation in sweetness, rather than energy density per se, is the key influence on fruit and vegetable preferences. Unfortunately, for fruit, it is not possible to distinguish these factors, because total sugar content is the primary determinant of energy density (here, for eight types of fruit, $r = 0.99$). However, this is not the case for vegetables, where starch or protein may contribute at least as much energy as sugars do (here, $r = -0.19$ for percentage of total sugars with kJ/g, $N = 13$, not significant). Energy density remained a significant predictor of preferences for vegetables when total sugar content (g/100 g) was controlled for, partial correlation $r(10) = 0.54$, $p < 0.05$, and when controlling for protein content, for vegetables $r(10) = 0.56$, and for fruit $r(5) = 0.69$, both $p < 0.05$.

A positive relationship between the energy content of foods and children's likes and dislikes has already been established experimentally (Birch, 1999), and is capitalised on by purveyors of 'fast food' and 'children's menus'. Our new results strongly suggest that energy density of foods is an important influence on preferences, even among 'healthy' foods such as fruit and vegetables. The correlations seem particularly striking given that fruit and vegetables are relatively low in energy: for instance, chocolate is fivefold as energy dense as banana. Moreover, fruit and vegetables are mostly very low in fat, and so lack the fatty sensory cues that young mammals could use to predict a rich source of energy (Ackroff, Vigorito, & Sclafani, 1990).

Awareness that energy density is a fundamental influence on children's liking for foods should help to inform strategies to encourage healthy eating. Children may more readily learn to accept the more energy-dense fruit and vegetables. These types might be chosen as a starting point for broader acceptance of fruit and vegetables, not only because of cultural generalisation within these food groups, but also because acceptance can spread between similar foods via sensory generalisation (Birch, Gunder, Grimm-Thomas, & Laing, 1998; Wardle et al., 2001).

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