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Two important exceptions to the relationship between energy density and fat content: Foods with reduced fat claims and high fat vegetable-based dishes.

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Abstract

Background:
High energy dense foods promote passive overconsumption of total energy and weight gain. High fat foods are usually energy dense.

Objective:
To test the hypothesis that many foods with reduced fat claims are relatively energy dense and that high fat vegetable-based dishes are relatively energy dilute.

Design:
Nutrient data were collected from foods in Melbourne supermarkets that had a reduced fat (RF) claim and had a full fat (FF) equivalent available. Recipes for high fat (HF) vegetable-based dishes were included if more than 30% energy was from fat but less than 10% from saturated fat. The dietary intake data (beverages removed) from the 1995 National Nutrition Survey were used for the reference relationships between energy density (ED) and percent energy as fat and carbohydrate and percent water by weight.

Results:
Both FF and RF foods were more energy dense than the Australian diet and the HF vegetable-based dishes were less energy dense. The Australian diet showed significant relationships with ED which were positive for percent energy as fat and negative for percent energy as carbohydrates. There were no such relationships
between ED and those macronutrients for the products with RF claims and HF vegetable-based dishes.

Conclusion:
While an overall reduction in dietary fat should reduce ED and protect against weight gain, there appear to be two important exceptions. A high intake of products with RF claims could lead to an increase in the ED of the diet and thus promote weight gain. Alternatively a high intake of vegetable-based foods, even if there is substantial added fat, could reduce ED and protect against weight gain.

Keywords: Energy Density, Reduced Fat, Low Fat, Weight Regulation
Introduction

In recent years there has been a dramatic increase in messages about dietary approaches to prevent weight gain or assist with weight loss, particularly about the need to reduce dietary fat intake. These messages have been strengthened by studies which have found that a reduction in dietary fat intake results in weight loss (1, 2).

A subsequent rise in public awareness and demands from the nutrition community (3) resulted in a flood of products with reduced fat (RF) claims onto the market (4). This may have constrained the promotion of dishes with high monounsaturated or polyunsaturated fat for the prevention of coronary heart disease for fear of promoting obesity.

The increased demand for low fat foods also coincided with the emergence of the so-called ‘American paradox’ (5) which is used to describe the growing prevalence of overweight and obesity in nations that have apparently reduced fat intake but increased consumption of “Low Fat” products. National data from Australia and America indicate that although there has been a reduction in percentage fat in the diet, overall energy intake has remained stable or even increased over the last 10 to 20 years (3, 6, 7)(NDS83).

This finding lead to the scientific community to explore the mechanisms behind the weight loss on a low fat diet which has consequently been shown to be the decrease in the energy density (ED) of the diet. Further laboratory-based studies have demonstrated that the macronutrient content of the diet does not have as large an impact on energy intake as does overall ED (8-12).
We isolated two food groups which may strongly impact on the ED of the diet and hypothesised that the usual relationships between ED and percent energy as fat and carbohydrate do not apply to products with RF claims or to high fat (HF), vegetable-based dishes. We examined these relationships in the context of those seen in the Australian diet.

**Methods:**

All products with a “Reduced fat”, “Low fat” or “Fat free” claim, or with product labelling that would lead consumers to believe they were lower in fat (such as “no fat”, “light”, “lite”, “skinny” or “diet”) were collected from three large supermarkets in high income areas of Melbourne, Australia. Products were included in the analysis if nutrient data were presented on the packaging and if there was an equivalent FF product available from the same manufacturer. A total of 133 RF/FF pairs were collected and homogeneous foods were grouped into 63 paired data points for analysis. This involved grouping items with the same product name but produced by different manufacturers (eg. cheeses and dips), or grouping foods with different flavours but the same manufacturer (eg. potato chips and yoghurt). The average of the nutritional information was applied to each of these categories. Where products required preparation with additional ingredients, and nutritional information was not available for the ‘package only’ ingredients, the nutritional data were analysed in the ‘ready to be consumed’ state following the manufacturers directions on the packaging.

Recipes for HF vegetable-based dishes were obtained from recipe books and internet recipe sites and analysed for nutrient content using Australian food composition.
databases (AUSNUT) (Get ref from Tim). Dishes were excluded if they contained
less than 30% energy from fat or more than 10% saturated fat (SFA). This latter
criterion was used to ensure that the dishes met the current dietary guidelines for SFA.
In practice, because vegetable oils contain some SFA and the amount of oil being
used was considerable, we needed to exclude recipes with significant meat and dairy
products to limit sources of SFA. The example of dishes included were grilled
Mediterranean vegetables with cous cous, cumin rice with eggplant and peppers,
layered potato cake, marinated grilled vegetables, and broccoli and tofu stir fry.

The Australian dietary intake data were 24 hour recall data from the 1995 Australian
National Nutrition Survey (NNS95) (7) for the population 2 years old and over. All
beverages were removed from the data because fluids have very different ED values
to solid foods and the physiological recognition of energy intake from fluids appears
to be different from solids (13). Fluids that would be consumed as part of foods such
as salad dressings, and semi-fluids such as yoghurts, were included.

Statistics

Linear regression lines were calculated for the relationship between ED and percent
energy as fat and carbohydrate and percent water by weight for the FF and RF foods
and the HF vegetable-based dishes.

A dependant $t$ test was used to compare predicted and observed change in total energy
from FF to RF products. Predicted change was calculated by determining the
difference in fat between FF and RF pairs, subtracting the fat difference in grams from
the FF products and substituting the weight of fat with the ED of the RF product.
For the population diet, linear regression lines were calculated for ED versus percent energy as fat, percent energy as carbohydrate, and percent water by weight from the NNS95. “Prediction bands” were also calculated to capture 95% of the population. These were plotted and used to represent the Australian population relationships as a dietary context for the relationships within the food products.

The ED relationships within the population data were not statistically compared to the ED relationships in the food data because they were fundamentally different and there were substantial differences in sample sizes.

Results:

The composition of the FF and RF foods, HF vegetable-based dishes and nutrient intake of the Australian diet are presented in Table 1. RF foods were significantly lower in fat and ED when compared to their equivalent FF products (P<0.0001) however the average ED of the RF foods was higher compared to the average Australian diet. Carbohydrate content was higher in the RF products compared to the FF foods and the population diet. The water content of the RF products was also higher than that of the FF products but these were both substantially lower than the Australian diet. On the other hand, HF vegetable-based dishes had on average more than 50% of energy from fat, but were less energy dense than the Australian diet. These dishes were low in energy from carbohydrates but were on average almost 80% water by weight.
FF/RF food pairs were analysed to determine if the observed decrease in fat content gave a concomitant decrease in ED. The predicted decrease in ED assumed that the grams of fat removed were replaced by equivalent grams of the lower fat product. On average the observed reduction in ED from FF to RF food pairs was not significantly different from the predicted values, although there was a substantial spread of data points around the line of identity (Fig 1).

For RF products there was no relationship between ED and percent energy as fat ($\beta = 0.04$, 95% confidence interval [CI] = -0.02 to 0.09) (Fig 2). In contrast, the population diet showed a significant positive relationship between fat content and ED ($\beta = 0.112$, 95% CI = 0.108 to 0.116). FF products also demonstrated a significant positive relationship between ED and percent energy as fat ($\beta = 0.08$, 95% CI = 0.01 to 0.15).

There was no relationship between percent energy as carbohydrate and ED for RF products ($\beta = -0.01$, 95% CI = -0.06 to 0.05) whereas the population dietary data ($\beta = -0.047$, 95% CI = -0.051 to -0.043), and the FF products ($\beta = -0.07$, 95% CI =-0.15 to 0.00) showed significant negative relationships (Fig 3). There was a cluster of RF foods that were low in fat (<25% energy) but high in carbohydrates (>60% energy) and ED (~15kJ/g) which clearly influenced fat and carbohydrate relationships with ED. This group of products consisted of low water content foods such as potato chips, biscuits, margarine, peanut butter and a chocolate bar.

There was a consistent negative relationship between water content and ED for RF foods ($\beta = -0.20$, 95% CI = -0.21 to -0.18), FF foods ($\beta = -0.24$, 95% CI =-0.26 to -
0.22) and the population diet ($\beta = -0.208, 95\% \text{ CI} = -0.209 \text{ to } -0.207$). (Fig 4). The clusters of RF, energy dense products mentioned above can be seen to have low water content.

For the HF vegetable-based dishes, there was no correlation between percent energy as fat and ED of HF vegetable-based dishes ($\beta = -0.02, 95\% \text{ CI} = -0.06 \text{ to } 0.01$) (Fig 5) and a marginal positive correlation between ED and percent energy as carbohydrate ($\beta = 0.035, 95\% \text{ CI} = 0.00 \text{ to } 0.07$) (Fig 6). The relationship between ED and percent water by weight in the HF vegetable-based dishes ($\beta = -0.17, 95\% \text{ CI} = -0.19 \text{ to } -0.15$) is shown in Fig 7. There was an obvious clustering of the HF vegetable-based dishes at the high water content end of the relationship.

Discussion:

This study assessed the relationships between energy density (ED) and dietary macronutrients within the Australian population diet, reduced fat (RF) foods, their full fat (FF) equivalents, and high fat (HF) vegetable-based dishes. Previous studies (8-12) have identified some of these anomalies to the fat/ED relationship, and we have put these into a population diet context.

These results demonstrate that although RF products were significantly lower in fat and ED than their FF equivalents, they were higher in ED than the Australian diet. This is because the RF products contained more carbohydrates (mainly sugars) than both the FF products and the population diet, and considerably less water than the Australian diet. Alternatively, even though HF vegetable-based dishes attained more
than 50% energy from fat, the ED was less than that of the population diet due to the energy dilute nature of the vegetable base.

RF products were still on average almost 50% more energy dense than the Australian diet even though there was a proportional reduction in ED with a reduction in fat content from FF to RF equivalents. Some food pairs showed much less change in ED than predicted, for example particular brands of potato chips, peanut butter and chocolate chip cookies. Other product pairs actually demonstrated a change in ED that was greater than expected, such as certain brands of yoghurt. However there did not seem to be any distinguishing characteristics of products that were either higher or lower in ED than predicted.

The Australian population dietary data showed that ED was positively related to percent energy as fat and negatively related to percent energy as carbohydrate. We have shown that RF foods and HF vegetable-based dishes are important exceptions to these relationships. The high ED and lack of relationship between percent energy as fat and carbohydrate in foods with a RF claim may be due to the high carbohydrate content (sugar) and the low water content. On the other hand, we expected the HF vegetable-based dishes to have a low ED because of the high water content, however as the proportion of fat in these dishes increased, there was little if any effect on ED. What seemed to raise the ED was an increase in the proportion of carbohydrates. This appeared to be due to the addition of ingredients such as rice, pasta and couscous to an energy dilute base such as vegetables. Most of the more energy dense dishes contained relatively large amounts of these cereals, whereas the low ED dishes contained mainly vegetables.
It still holds that HF foods are the most energy dense, and unrestricted consumption will increase the risk weight gain (14, 15). But these exceptions mean that a high intake of products with RF claims could increase ED and promote weight gain. Alternatively, a high intake of vegetable-based dishes, even those with a lot of added oil, may decrease ED and reduce risk of weight gain.

Several studies (8-12) have examined the effect of changing dietary fat content without altering the ED of the overall diet (or meal). Although the amount of fat (between 20 and 60% of energy) and other macronutrients consumed in each diet varied, the overall weight of food intake was relatively stable. Results indicate that subjects consumed similar ad libitum energy intake despite large variations in the composition of the diets. Two studies (14, 15) looked at changing ED without altering the diet composition and again found that similar weights of food were consumed, however because the ED of the diets varied, subjects consumed up to 1.7 times the amount of energy on the high ED diets compared to the low ED diets. These and other studies suggest that only HF, high energy dense diets result in passive overconsumption, not HF diets per se (16).

Because many RF products contain as much energy as the original FF foods (17), and consumers perceive RF products to be ‘guilt-free’ (3, 5) it has been suggested that replacing FF foods with RF alternatives may also lead to passive overconsumption. Studies show that people will consume more of a product labelled “Low Fat” because they feel it does not violate self-imposed dietary restrictions (18-20).
Food manufacturers were quick to recognise this marketing concept and responded by introducing nutrition claims on packaging. Over the last ten years in the US, 20 – 37% of new products have nutrition claims, with over half of those having either a “Low Fat” or “Reduced Fat” claim (4). In Australia these claims are self-regulated and can be easily violated by deceptive marketing by the manufacturers. Our study found several examples of this. Three products that made a “Percent Fat Free” claim had the same macronutrient composition as an equivalent product sold by the same manufacturer with no claim made on the packaging. Three more products making a “Lite” claim contained the same dry ingredients as the manufacturer's regular product, but were packaged in lighter packaging with instructions to use different additional ingredients for preparation. These marketing strategies are employed because consumers often give foods a more positive or negative image than they deserve based on the packaging (21).

The high consumption of low fat products may help to explain the so called ‘American Paradox’. This is the paradox of increasing obesity prevalence in parallel with increases in percent carbohydrate intake, total energy intake and the availability of “Low Fat” products (22). Therefore, while the percent of energy as fat consumed has decreased, the absolute intake of fat grams has remained stable and the overall energy intake of the diet has increased by as much as 1200 kilojoules per day (3, 23). It has also been argued that dietary fat intake has not decreased but people are more likely to underreport their fat intake as obesity rises (24).

This obsession with “Low Fat” may also prevent people from gaining other health benefits from particular dietary fats. Diets high in unsaturated fat, such as olive oil,
and low in dairy and animal fats, may be protective against coronary heart disease (CHD) (25). Kushi et al has shown that a diet high in fat but vegetable-based may not contribute to obesity. Therefore a diet relatively high in monounsaturated or polyunsaturated oils could be promoted to not only prevent weight gain but also to protect against CHD.

**Implications:**

Manufactured foods with “Low Fat” claims are often energy dense and high consumption of them (promoted by marketing messages and consumer perceptions) may promote weight gain. Food regulations in relation to “Low Fat” claims may need to include energy density criteria.

Marketing of “Low Fat” products that imply that a high consumption will not cause weight gain and are therefore “guilt free”, need to be constrained.

Nutrition education messages about decreasing fat intake should be modification to caution about overconsumption of “Low Fat” products.

Nutrition education messages about coronary heart disease prevention can be more confident about the promotion of vegetable-based dishes that are relatively high in monounsaturated and polyunsaturated fats.
References:

Table 1: Composition of the Australian population diet and foods with reduced fat claims, their full fat equivalents, high fat (HF) vegetable-based dishes (mean± standard deviation).

<table>
<thead>
<tr>
<th></th>
<th>Australian Diet</th>
<th>Reduced Fat Foods</th>
<th>Full Fat Foods</th>
<th>HF vegetable-based dishes</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>10794</td>
<td>63</td>
<td>63</td>
<td>47</td>
</tr>
<tr>
<td>Energy Density (kJ/g)</td>
<td>5.1 ± 1.6</td>
<td>7.7 ± 5.5</td>
<td>10.2 ± 6.5</td>
<td>3.9 ± 1.5</td>
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<tr>
<td>Energy as Fat (%)</td>
<td>32.5 ± 8.9</td>
<td>30.8 ± 25.6</td>
<td>50.5 ± 22.6</td>
<td>53.9 ± 13.9</td>
</tr>
<tr>
<td>Energy as Carbohydrate (%)</td>
<td>44.8 ± 10.1</td>
<td>52.3 ± 25.2</td>
<td>36.8 ± 22.4</td>
<td>31.3 ± 12.4</td>
</tr>
<tr>
<td>Weight as Water (%)</td>
<td>72.3 ± 7.9</td>
<td>63.1 ± 26.6</td>
<td>58.2 ± 25.9</td>
<td>79.4 ± 8.2</td>
</tr>
</tbody>
</table>
Figure 1: Predicted compared to observed difference in energy density between reduced fat foods and full fat foods. Dotted line is the line of identity. No statistical difference between predicted and observed.

Figure 2: Energy density compared to percent energy as fat in reduced fat and high fat foods. Circles and solid regression line represent reduced fat foods, dotted line is regression for full fat products, and parallel lighter lines are for the population diet (regression and 95% prediction bands).

Figure 3: Energy density compared to percent carbohydrate as fat in reduced fat and high fat foods. Circles and solid regression line represent reduced fat foods, dotted line is regression for full fat products, and parallel lighter lines are for the population diet (regression and 95% prediction bands).

Figure 4: Energy density compared to percent water by weight in reduced fat and high fat foods. Circles and solid regression line represent reduced fat foods, dotted line is regression for full fat products, and parallel lighter lines are for the population diet (regression and 95% prediction bands).

Figure 5: Energy density compared to percent energy as fat in high fat, vegetable-based dishes. Circles and solid regression line represent high fat, vegetable-based dished and the parallel lighter lines are for the population diet (regression and 95% prediction bands).
Figure 6: Energy density compared to percent energy as carbohydrate in high fat, vegetable-based dishes. Circles and solid regression line represent high fat, vegetable-based dishes and the parallel lighter lines are for the population diet (regression and 95% prediction bands).

Figure 7: Energy density compared to percent water by weight in high fat, vegetable-based dishes. Circles and solid regression line represent high fat, vegetable-based dishes and the parallel lighter lines are for the population diet (regression and 95% prediction bands).