Peer-reviewed | Manuscript received: October 2, 2012 | Revision accepted: January 1, 2013

Energy Density and Cost of Foods in Germany

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Summary

There is considerable evidence that low socio-economic status is associated with a higher prevalence of obesity. It was hypothesized that foods with higher energy density (kcal/100 g) have lower energy costs (price per kcal) than foods with lower energy density. Therefore a low disposable income could contribute to the preferred consumption of foods with high energy density. Thus energy requirements can be met with relatively little money. Data on energy costs and energy density of foods from different countries support this hypothesis. For Germany, no systematic data on this relationship is available.

Prices and package sizes of 602 foods from 9 different food groups (fruit, vegetables, noodles-rice-bread, meat, meat products, milk and milk products, fats, sweets and nibbles, convenience foods) were recorded in supermarkets and shops (bakeries, butchers). Energy content was also recorded, if this was listed on the package, or obtained from nutrient databases if necessary. Energy density was calculated as kcal per 100 g. Energy costs were calculated as € per 100 kcal.

Energy costs correlated negatively with energy density ($r = -0.57$, $p < 0.001$) over all 602 food samples. In addition, there was a significant negative correlation within most food groups.

In Germany, as in other countries, foods with high energy density are relatively cheap. Therefore, economic constraints make it likely that food of high energy density is preferably consumed in low income groups, contributing to excessive energy intake.

Keywords: Energy density, food costs, obesity, income, energy content

Citation:
Westenhöfer J (2013) Energy Density and Cost of Foods in Germany. Ernaehrungs Umschau international 60(3): 30–35

This article is available online: DOI 10.4455/eu.2013.008

Introduction

According to representative surveys performed by the Robert Koch Institute (RKI) in 2010, 16.1 % of adult men and 15.6 % of adult women in Germany are obese. The corresponding figures in the 2009 Microcensus are 15.7 % for men and 13.8 % for women [1]. These two studies also recorded 44 % overweight men and 29 % overweight women. The RKI Study on Adult Health in Germany (DEGS1) [2] not only queried weight and height between 2008 and 2011, but also measured these parameters. The prevalence of obesity was as high as 23.3 % in men and 23.9 % in women [1]. On the basis of data collected in 2005 and 2006, the National Consumption Study II found that 20.5 % of men and 21.2 % of women were obese [3]. Obesity is one of the most important public health problems in Germany, in view of the diseases it accompanies or causes.

Socio-economic status and consumption pattern

It is also well documented that obesity in Germany exhibits a marked social gradient. The prevalence of obesity is greater in groups of lower socio-economic status, particularly with lower school-leaving exams [1, 3] and lower incomes [3]. Several possible causes for this have been considered. One possibility would be differences in attitudes to sport in different social classes [4]. Alternatively, the social gradient might be linked to differences in the acceptability or unacceptability of increased body weight [4]. Another cause might be lower consumption of fruit and fresh vegetables due to relative lack of money [4]. Thus the National Consumption Study II found that members of lower social classes consume less vegetables, fruit and fish, but more fat, meat, sausage products and lemonade [5]. In the context of the recommendations of

the German Nutrition Society (DGE), this consumption pattern can be designated as "unhealthy". It nevertheless remains uncertain whether this consumption pattern is really due to relative poverty or to differences in attitudes. Moreover, describing this consumption pattern as "unhealthy" tends to neglect another aspect, which may be important or even decisive, namely that foods that are more rarely consumed tend to have lower energy density and foods that are consumed more frequently tend to have high energy density. Energy density is defined as "energy content (in kcal or kJ) per unit weight (mostly g, 100 g or kg)" [6]. Foods with low energy density mostly have high water content, whereas a high content of fat and carbohydrates leads to higher energy density.

Influence of energy density on consumption

Several experimental studies have shown that foods or meals of low energy density are accompanied by low energy intake and a high energy density is accompanied by high energy intake [7]. One reason for this may be that many energy dense foods are particularly tasty, due to their high content of fat and/or sugar. However, the most important finding is that even when the taste is constant and the energy density is manipulated in such a way that the test subject fails to notice this, the consumed weight or volume of food is constant and the energy intake is raised – solely due to the increased energy density [8, 9]. As the subjects do not actively bring about this increased energy intake, which is usually unintentional and unnoticed, this is designated as "passive overconsumption" [10].

A current systematic review of the literature [11] concluded that there is strong and consistent evidence from interventional and cohort studies that, in adults, a low energy density is accompanied by lower body weight and better weight stabilisation. For children and adolescents, there is moderately strong evidence from longitudinal studies that nutrition with high energy density is associated with obesity.

Energy density and food costs

Drewnowski et al. have documented that in the USA and France there is an inverse relationship between energy density and energy-related food costs (as € or US$ per 1 000 kcal or MJ) [12–15]. This means that energy-dense foods provide the same nutritional energy at a lower price, while the same nutritional energy is more expensive for foods with lower energy density. Moreover, an observational study on 837 adults in France showed that there is an inverse correlation between energy density and price: nutrition with high energy density costs less than nutrition with low energy density. This applies not only to the individual foods, but also to overall nutrition [14].

This link between energy density and price could be regarded as an important mediator for the relationship between socio-economic status and the prevalence of overweight. It was originally suggested by Basiotis [16, 17] that households with highly restricted financial possibilities initially consume cheaper foods with higher energy density to cover their energy requirements. The energy intake only becomes less than required if the available financial are even more severely restricted. This mechanism comes into play when there is no longer enough money to cover the energy requirements with foods that the subject would actually like to consume. However, it is unclear whether this correlation can be generalised to a broader spectrum of incomes.

It may be assumed that there is a similar relationship in Germany between energy density and food costs – even though the corresponding data have not yet been published. There are some studies that investigate whether healthy nutrition in accordance with the recommendations is more expensive in Germany than conventional nutrition [18–20]. It was found that this is not necessarily the case. It is more important whether expensive or cheap foods tend to be selected in the individual food groups and whether basic ingredients are used or preprocessed and expensive brand products.

However, these studies did not directly address the correlation between costs and energy density. It is therefore the aim of the present study to investigate whether there is an inverse relationship between energy density and food costs in Germany too.

Methods

Data collection

During April and May 2012 in the summer term of 2012, students in the Public Health Nutrition course at the University of Applied Sciences in Hamburg collected the data for nine different food groups in different supermarkets (including discount markets) and retail outlets (bakeries and butchers) within the Hamburg region.

The selection of the nine food groups was orientated on the seven food groups in the DGE nutritional section. However, drinks were excluded from the present study, firstly because the significance of drinks in satiety and energy intake is fundamentally different from that of solid foods, and secondly because the price structure of tap water and drinks prepared from it is quite different. Aside from the food groups in the

DGE nutritional section, sweets, nibbles and processed foods were considered as a group, as they can play an important role in nutrition and energy intake. The food group "meat, sausage, eggs" was split into meat on the one hand and sausage and meat products on the other hand as it was suspected that there were marked differences in energy density in this case.

Between six and ten typical foods were selected for each food group (◆ Table 1). The foods were selected by forming a consensus among study participants, with the aim of covering typical foods, while retaining an appropriate range. Moreover, with fruit and vegetables, an effort was made to consider different preparations of these foods – fresh, dried, canned or deep frozen. For each of the total of 70 foods, the data were collected in at least two different shops or supermarkets. The shops were selected unsystematically, although care was taken that at least one discount store and at least one other supermarket was selected for each food group, as well as a butcher for meat and meat products and a baker for bread. If there was more than one offer for a food in a supermarket or shop, the data for the cheapest and most expensive offer were recorded, together with the data for the most widely spread or most strikingly positioned offer. Special offers were not considered. The evaluation included a total of 602 different food offers.

For each food, the pack size (in g) and the pack price (in €) were recorded, in so far as these were given on the pack. For unpacked foods, the kg price was recorded. If no nutritional values had been provided by the manufacturer, the energy content was determined with the program DGE-PC Version 5.0, on the basis of the German Food Key (BLS), Version 3.01.

Group	Food
fruit	*fresh:* apples, bananas, grapes *tins:* peach, pineapple *dried:* dates
vegetables	*fresh:* potatoes, carrots, paprika *tins:* maize *deep frozen:* mixed vegetables, broccoli
noodles, rice, bread	wholemeal bread, rye bread, black bread/pumpernickel, white bread, normal rice, basmati rice, parboiled rice, wheat noodles, wholemeal noodles
meat	chicken breast, chicken legs, pork escalope, chop, beef steak, minced beef, minced pork, mixed mince
meat products, sausage	little sausages, salami, liver sausage, mortadella, ham, bacon
milk and milk products	drinking milk 1.5 %, drinking milk 3.5 %, quark 20 %, quark 40 %, natural yoghurt 1.5 %, fruit yoghurt, fresh cheese, gouda 40 %, creme fraiche, buttermilk
fats	olive oil, rape oil, soya oil, sunflower oil, margarine, butter, semi-fat butter
sweets and nibbles	crisps, peanuts, milk chocolate, biscuits, gummi bears, salt pretzels, ice-cream
processed foods	tinned ravioli, deep frozen pizza, tinned soup, hamburger, fish fillet dish, frozen meat balls, chips, lasagne, spring rolls, Nasi goreng

Table 1: **Food groups and foods included in this investigation**

Data processing

The evaluation included two parameters; the energy density, defined as energy content in kcal pro 100 g of a food and energy costs, calculated as costs (in €) per 100 kcal of a food. Thus the energy costs do not correspond to the price of a food per g, but per 100 kcal nutritional energy. The distribution of the energy cost exhibited a large range and was highly skew. In order to investigate the interrelationship between energy density and energy costs, Spearman's rho was calculated as a parameter free measure of the correlation. The level of significance was specified as = 0.05. Descriptive statistics are given as mean ± standard deviation, as well as minimum, 25th percentile, median, 75th percentile and maximum.

Results

The energy density of the 602 food samples fluctuates between 19 kcal/100 g and 900 kcal/100 g and the energy costs between 0.02 €/100 kcal and 3.73 €/100 kcal, thus by a factor of more than 180.

◆ Table 2 shows the mean values and standard deviations for the nine food groups studied, as well as the correlation between energy density and energy costs. As expected, vegetables have the lowest energy density, followed by fruit. Fats have the highest energy density, followed by sweets and nibbles. The lowest mean energy costs are assigned to fats, followed by noodles, rice, bread and then sweets and nibbles. Vegetables have the highest mean energy costs.

For all 602 food samples, there was a significant inverse correlation between energy density and energy costs. The higher the energy density of a food, the lower are the costs per 100 kcal. This correlation is shown in ◆Figure 1. The inverse relationship between energy density and energy costs not only applied over all foods, but also within most food groups (◆Table 2). The significant correlation was only absent within the groups of milk and milk products and sweets and nibbles.

Discussion

The present study examined 70 typical foods in nine food groups, with a total of 602 samples, with respect to energy density and costs. The results show that in Germany too – as already documented in the USA and France [12–15] – there is an inverse correlation between the energy density of foods and the energy costs – in other words, between the costs of a food and the energy content. Foods with high energy density cost relatively little per calorie, while foods with low energy density are relatively expensive. This inverse correlation applied over the whole selection of foods, as well as within most food groups – with the exceptions of the milk and milk products group and the sweets and nibbles group.

Limitations

When interpreting the results, it must be born in mind that, although the 70 foods examined represent a broad cross-section of commercially available foods, they still only map a tiny fraction of the overall range of up to 40 000 articles in large supermarkets [21]. It is possible that other correlations would have been found with another shopping basket. As examples, we selected the highest and lowest prices, as well as the most widely spread offer. This could have introduced bias, in comparison to systematic recording of the prices. Moreover, the data collection was restricted to the region of Hamburg and the period of April to June 2012. Prices recorded at other times and in other regions might have led to different results. We nevertheless assume that the structure and basic conclusion of these correlations is reliable enough to represent the current situation in Germany.
We also wish to point out that the energy density of foods in the present study was expressed in €/kcal

Food Group (number of samples)	Energy Density (kcal/100g)	Energie Costs (€/100 kcal)	Correlation
fruit (n = 62)	96,7 ± 67,7 51 – 65 – 71 – 90 – 294	0,34 ± 0,19 0,09 – 0,19 – 0,29 – 0,41 – 0,91	–0,39[1]
vegetables (n = 63)	44,7 ± 23,4 19 – 26 – 32 – 70 – 89	0,78 ± 0,75 0,04 – 0,30 – 0,51 – 0,91 – 3,74	–0,59[2]
noodles, rice, bread (n = 96)	239,9 ± 67,3 137 – 220 – 265 – 351 – 378	0,11 ± 0,09 0,03 – 0,04 – 0,09 – 0,14 – 0,53	–0,63[2]
meat (n = 50)	174,6 ± 55,9 108 – 243 – 283 – 328 - 621	0,61 ± 0,50 0,12 – 0,26 – 0,45 – 0,87 – 2,15	–0,65[2]
sausage (n = 43)	282,8 ± 84,1 32 – 61 – 94 – 255 - 384	0,60 ± 0,52 0,12 – 0,27 – 0,48 – 0,75 – 2,82	–0,47[1]
milk, milk products (n = 100)	144,5 ± 111,8 32 – 61 – 94 – 255 - 384	0,19 ± 0,10 0,04 – 0,11 – 0,15 – 0,26 – 0,56	–0,01
fats (n = 60)	772,5 ± 177,2 350 – 720 – 819 – 828 – 900	0,08 ± 0,07 0,02 – 0,02 – 0,05 – 0,10 – 0,33	–0,64[2]
sweets, nibbles (n = 67)	454,3 ± 125,8 96 – 352 – 502 – 538 – 630	0,13 ± 0,08 0,04 – 0,07 – 0,12 – 0,17 – 0,51	0,00
processed foods (n = 61)	160,0 ± 82,4 21 – 98 – 147 – 240 – 376	0,34 ± 0,27 0,04 – 0,19 – 0,28 – 0,36 – 1,34	–0,41[1]
all (n = 602)	**256,6 ± 215,9** **19 – 80 – 217 – 350 – 900**	**0,32 ± 0,41** **0,02 – 0,10 – 0,18 – 0,36 – 3,74**	**–0,57[2]**

[1]p < 0,01; [2]p < 0,001

Table 2: **Energy density and energy costs, with correlations (Spearman's rho) between energy density and energy costs, both within groups and for all samples** (for each parameter, the first line gives the mean ± standard deviation; the second line gives the minimum, 25th percentile, median, 75th percentile and maximum)

rather than in €/g for the correlation with food costs. Although DREWNOWSKI et al. [12–15] expressed their results in terms of €/kcal, the use of €/g is more conventional, and is indeed normal in supermarkets. Our approach is based on the conception that people first attempt to cover their energy requirements. In this context, foods with low energy costs supply a specific quantity of nutritional energy more cheaply than foods with higher energy costs. The present study is a purely descriptive study, which simply examines the correlation for different foods between two parameters – energy density and costs. No causal conclusions are possible. The central finding of this study is that a high energy density is correlated with relatively low energy-related costs.

Secondary hypotheses

On the basis of this result, further hypotheses can be formulated. On the basis of overall food prices, it appears that nutrition with high energy density costs less than nutrition with low energy density. This has already been demonstrated for France [14]. According to the results of the 2011 Nestlé Study [22], 36 % of subjects of high socio-economic status agree with the statement that they look for particularly low prices. The corresponding figures for intermediate and low socio-economic status are 59 and 71 %, respectively. As many consumers in Germany are also very sensitive about food prices, this would tend to favour nutrition with energy dense foods. As discussed in detail in the Introduction, this can lead to more overall nutritional energy being consumed [7–10], resulting in excessive nutrition. Increases in weight, overweight and obesity become more probable [7, 11]. The relatively low prices of foods with high energy density could then contribute to the relatively high frequency of overweight and obesity in the population.

We should also remember that BASIOTIS [16, 17] considered that households with few financial resources tend to favour foods with high energy density and that consumers of low socio-economic status pay more attention to low prices. The link between energy density and food prices then presents a possible cause for the socially imbalanced distribution of overweight and obesity. In the context of the cited articles, the present results lead to two secondary hypotheses, which must be examined in further studies:

1. The low prices for foods with high energy density contribute to the preferential purchase and consumption of foods of high energy density.
2. This effect is particularly marked for consumers with low income.

These hypotheses indicate that excessive nutrition and obesity are not purely a question of education or attitudes, but have at least an economic element. There has been little discussion in Germany of this economic dimension of obesity – the relatively low costs of foods of high energy density.

It is theoretically conceivable that official support could be used to make food with low energy density cheaper. Alternatively, or additionally, foods with high energy density could be made more expensive with higher taxation or by removing direct or indirect subventions. It would be desirable to provide reliable evidence for this on the basis of interventional studies of high methodological quality.

In 2011, an attempt was made in Denmark to influence the price structure of foods by means of a fat tax.[1] In other words, foods with high energy density are taxed on the basis of their fat content [23]. Meanwhile, this fat tax was cancelled. According to the Danish government, this was because of the high costs and high administrative effort, particularly as the desired results were not achieved [24]. On the other

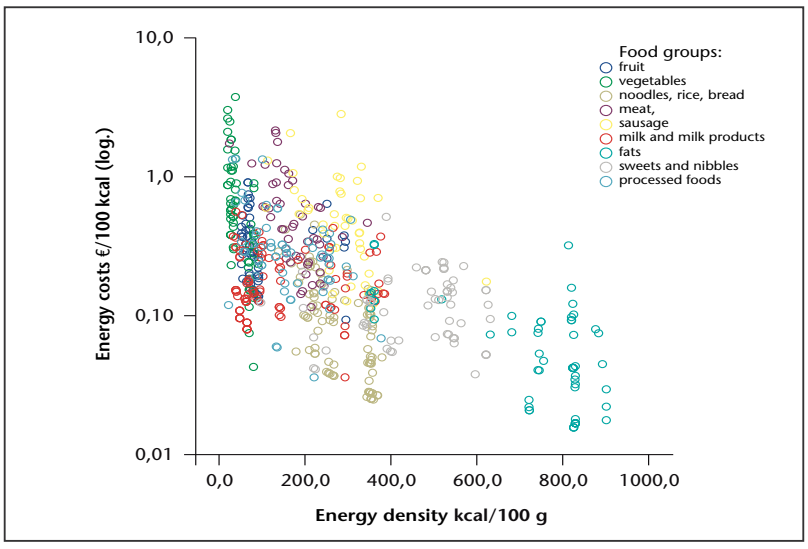

Figure 1: **Correlation between energy density (kcal/100 g) and energy costs (€/100 kcal) in foods.** Because of their wide range, energy costs are expressed as logarithms [log.].

[1] See the commentary from Hans HAUNER on the taxation of unhealthy foods in Ernährungs Umschau 2/2013, pp. M82–M83

hand, no reliable scientific evidence has yet been published on this natural "field trial". Thus, no final conclusion is possible about any control effects that may have been achieved and how important the undesired side effects were - such as shopping tourism and negative social effects.

An important objective of future research would be to perform systematic studies to establish which changes in price structure might cause a desirable change in eating behaviour, the potential problems linked to such an intervention and how any change in price structure might be implemented in a politically and socially acceptable manner.

Acknowledgement
I wish to thank the students in the Public Health Nutrition course in the summer term of 2012 for their committed and careful data collection.

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Conflict of Interest
The author declares no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

References

1. *Robert Koch-Institut (RKI) (2012) Daten und Fakten: Ergebnisse der Studie „Gesundheit in Deutschland aktuell 2010". URL: www.gbe-bund.de/gbe10/owards.prc_show_pdf?p_id=15239&p_sprache=d&p_uid=gast&p_aid=79459172&p_lfd_nr=41 Zugriff 13.09.12*
2. *Gößwald A, Lange M, Kamtsiuris P et al. (2012) DEGS: Studie zur Gesundheit Erwachsener in Deutschland. Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz 55: 775–780*
3. *Max Rubner-Institut (MRI). Bundesforschungsinstitut für Ernährung und Lebensmittel. Nationale Verzehrs Studie II. Ergebnisbericht Teil 1. Die bundesweite Befragung zur Ernährung von Jugendlichen und Erwachsenen. Max Rubner-Institut, Karlsruhe (2008)*
4. *Benecke A, Vogel H. Übergewicht und Adipositas. Robert Koch-Institut (RKI), Berlin (2003)*
5. *Max Rubner-Institut (MRI). Bundesforschungsinstitut für Ernährung und Lebensmittel. Nationale Verzehrs Studie II. Ergebnisbericht Teil 2. Die bundesweite Befragung zur Ernährung von Jugendlichen und Erwachsenen. Max Rubner-Institut, Karlsruhe (2008)*
6. *Erbersdobler HF (2005) Die Energiedichte, eine vernachlässigte Größe? Ernährungs Umschau 52: 136–139*
7. *Ello-Martin JA, Ledikwe JH, Rolls BJ (2005) The influence of food portion size and energy density on energy intake: implications for weight management. Am J Clin Nutr 82: 236S–241S*
8. *Bell EA, Castellanos VH, Pelkman CL et al. (1998) Energy density of foods affects energy intake in normal-weight women. Am J Clin Nutr 67: 412–420*
9. *Rolls BJ (2000) The role of energy density in the overconsumption of fat. J Nutr 130: 268S–271S*
10. *Blundell JE, Macdiarmid JI (1997) Passive overconsumption. Fat intake and short-term energy balance. Ann N Y Acad Sci 827: 392–407*
11. *Pérez-Escamilla R, Obbagy JE, Altman JM et al. (2012) Dietary energy density and body weight in adults and children: a systematic review. J Acad Nutr Diet 112: 671–684*
12. *Drewnowski A, Specter SE (2004) Poverty and obesity: the role of energy density and energy costs. Am J Clin Nutr 79: 6–16*
13. *Drewnowski A, Darmon N (2005) The economics of obesity: dietary energy density and energy cost. Am J Clin Nutr 82: 265S–273S*
14. *Darmon N, Briend A, Drewnowski A (2004) Energy-dense diets are associated with lower diet costs: a community study of French adults. Public Health Nutr 7: 21–27*
15. *Drewnowski A (2010) The cost of US foods as related to their nutritive value. Am J Clin Nutr 92: 1181–1188*
16. *Basiotis PP. Validity of the Self-Reported Food Sufficiency Status Item in the U.S. Department of Agriculture's Food Consumption Surveys. American Council on Consumer Interests 38th Annual Conference: The Proceedings. Columbia, Mo., (1992)*
17. *Basiotis PP, Lino M (2002) Food Insufficiency and Prevalence of Overweight among Adult Women. Nutrition Insights [Internet] 26*
18. *Mertens E, Schneider K, Claupein E et al. (2008) Lebensmittelkosten bei verschiedenen Ernährungsweisen. Ernährungs Umschau 55: 139–148*
19. *Wagner C, Gedrich K, Karg G (2008) Lebensmittelkosten im Rahmen einer vollwertigen Ernährung. Ernährungs Umschau 55: 216–227*
20. *Alexy U, Clausen K, Köpper A et al. (2012) Wie teuer ist die Ernährung von Kindern und Jugendlichen bei verschiedenen Szenarien der Lebensmittelauswahl? Ernährungs Umschau 59: 72–77*
21. *Supermarkt – Wikipedia. URL: http://de.wikipedia.org/wiki/Supermarkt Zugriff 13.09.12*
22. *Nestlé Deutschland AG (Hg). Nestlé Studie 2011. So is(s)t Deutschland. Ein Spiegel der Gesellschaft. Deutscher Fachverlag, Frankfurt (2011)*
23. *Smed S (2012) Financial penalties on foods: the fat tax in Denmark. Nutrition Bulletin 37: 142–147*
24. *Dänemark schafft Fettsteuer ab – SPIEGEL ONLINE. URL: www.spiegel.de/wirtschaft/soziales/daenemark-schafft-fettsteuer-ab-a-866537.html Zugriff 21.01.13*

DOI: 10.4455/eu.2013.008