The relation between food price, energy density and diet quality

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Summary

Low energy density diet, high in fruits and vegetables, is related to lower obesity risk and to better health status, but is more expensive. High energy density diet, high in added sugar and fats, is more affordable, but is related to higher obesity and chronic diseases risk. The aim of this study was to report prices according to energy density (low vs. high) of food items and to show how food affordability could affect food choice and consumers' health. Data was collected for 137 raw and processed foods from three purchase sites in Zagreb (one representative for supermarket, one smaller shop and green market). Results showed that low energy density food is more expensive than high energy density food (for example, the price of 1000 kcal from green zucchini (15 kcal/100 g) is 124.20 kn while the price of 1000 kcal from sour cream (138 kcal/100 g) is 13.99 kn). Food energy price was significantly different ($p<0.05$) between food groups with highest price for vegetable products (159.04 ± 36.18 kn/1000 kcal) and raw vegetables (97.90 ± 50.13 kn/1000 kcal) and lowest for fats (8.49 ± 1.22 kn/1000 kcal) and cereals and products (5.66 ± 0.76 kn/1000 kcal). Negative correlation (Spearman $r=-0.72$, $p<0.0001$) was observed for energy density (kcal/100 g) and price of 1000 kcal. Therefore, it is advisable to develop strategies in order to reduce price of low energy density food and encourage its intake since it would improve diet quality, which could lead to better costumers' health.

Keywords: energy density, food price, food choice, diet quality, obesity

Introduction

The quality of consumers' diet depends on their economic status, and the impact of food prices on food intake is a subject of increasing interest (American Dietetic Association, 2007). Price is one of the most important factors that influence food choice (Lappalainen et al., 1998). Kettings et al. (2009) found that fruits and vegetables represented 44 % of the total price of healthy diet. Yang and Chiou (2010) found that health claims combined with the price alterations have the greatest impact on consumers' food choice.

Energy density, expressed as kcal/g, is a measure of available energy *per* mass unit of certain foods and can be used to describe certain foods or entire food menu. Energy density is an indicator of the food quality (Drewnowski, 2003) and is correlated with the nutrient density (Andrieu et al., 2006). Nutrient density expresses vitamin and mineral intakes per energy unit, μg or mg/1000 kcal. Azadbakht and Esmaillzadeh (2012) found that a higher dietary energy density is associated with unhealthy food choices where consumers in top tertile of dietary energy density had higher intakes of vegetable oils and high-fat dairy products and lower intakes of fruit, vegetable, meat, and fish.

Development in agriculture and food industry resulted in the production of foods rich in energy and poor in essential nutrients (called empty calories) available to consumers at a very low price. Diet rich in energy contains added sugars and has high fat content and has desirable organoleptic properties (human taste preferences for sugar and fat are either innate or acquired very early in life).

In Croatia, just like all over the world, consumption of high energy dense foods is increasing. In 2010, Croats spent 32 % of their household budgets on food and drinks (GfK Croatia, 2011). In 2008, compared to the end of the 2007, food price rose almost 14 %, which is why food consumption was reduced in the same extent (Koludrović, 2008). According to the data from the Croatian Bureau of Statistics for 2012, the amount of consumed food by households has increased mainly in favour of cereals and cereal products, meat and meat products, fish, eggs, milk and dairy products, while the consumption of fruits and vegetables decreased.

Between 1985 and 2010 the price of beverages sweetened with high-fructose corn syrup dropped 24 %, and by 2006 American children consumed 130 kcal/day from these beverages. Over the same period, the price of fresh fruits and vegetables rose 39 % (Scientific American's Board of Editors, 2012). Increased price of

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meat and dairy products caused a reduced intake of vitamin B_{12} (Iannotti et al., 2012).

According to epidemiological studies, a diet consisting of added sugars and fats, i.e. high energy density diet, is associated with a higher risk of obesity and type 2 diabetes (Liu, 2002).

Obesity is not only medical, but has become a social and public health problem. The incidence of overweight and obesity is increasing, both worldwide and in Croatia. Data from anthropometric surveys conducted in Croatia in 2003 among adult population aged 18-74 years, indicate a growing problem of overweight and obesity. On average 58.2 % of women and 68.3 % of men are in the overweight range (body mass index, BMI > 25 kg/m²); 35.5 % of women and 46.7 % of men have BMI 25-29.9 kg /m², and 22.7 % of women and 21.6 % of men are obese (BMI > 30 kg/m²) (Antonić-Degač et al., 2007).

One strategy for tackling the problem of obesity is to encourage the consumption of low energy density foods. Williams et al. (2013) found that the 20 % reduction in energy density was associated with a 9-15 % decrease in daily energy intake, depending on the method. The finding that all three methods applied: (1) decreasing fat, (2) increasing fruit and vegetables, and (3) adding water, reduced energy intake at meals and over the day suggests that individuals can modify the energy density of foods using their preferred methods or a combination of methods, such as replacing oil with applesauce when baking (fat reduction along with increased fruit intake). The practical implication is that a variety of diet compositions can be recommended to reduce overall dietary energy density in order to moderate energy intake. Raynor et al. (2012) found that an energy density prescription reduced energy and percent of energy from fat and increased dietary fiber intake and servings of fruit *per* day. The low energy density prescription also produced significant weight loss. A low energy density diet prescription may provide a singular recommendation that can assist individuals with losing weight and increasing fruit intake.

Monitoring food prices is an important part of the concept of public health to prevent diseases associated with inadequate nutrition. Therefore, the aim of this paper was to report the food prices on the Croatian market, to investigate whether diet rich in fresh fruits and vegetables costs more than a diet rich in sugars and fats, to determine whether there is a difference in the price of low and high energy density foods, and to highlight the importance of the impact of food prices on food quality and thus on human health.

Materials and methods

The experimental part included collection and calculations of price and energy density data for 137 foods (raw and processed) and creation and comparison of two daily menus differing in energy density. Data for food prices was compared with previous similar study from 2008 (Koludrović, 2008).

Energy and price data collection

Collected data included regular food prices (which does not include discounts or actions) (kn/kg), energy density of packed foods/products (kcal/100 g) and the package size (g). Data were taken at three locations: (1) Konzum (representative for supermarket), (2) shop 'Palma' (representative for small shop), and (3) the Dolac market (representative for green market). Koludrović in her research (2008) also had supermarket, small shop and green market. All three locations for both this and previous survey were in Zagreb. Data were taken in the time period from April to July 2012. Food selection was based on a food list from Croatian food composition tables using the same division within food groups (cereals, fruits, vegetables, meat, fish, eggs, legumes and nuts, milk and dairy products, fats and oils, sugar, honey and sweets, juices, soft drinks and beverages) (Kaić-Rak and Antonić, 1990). Where appropriate, nutrition information declared on the food product was used for the information of energy density.

Calculations and food prices comparison

The energy content for every food was converted to kilocalories *per* kilogram (kcal/kg). Prices that were not expressed *per* kilogram of food, were recalculated using package weight data. The average price *per* kilogram (kn/kg) was calculated from three prices of each food. The price data (kn/kg) and kilocalories *per* kilogram (kcal/kg) were used to calculate a price for 1000 kcal (kn/1000 kcal) for each food. Energy value for instant drinks (vitamin drink Cedevita, cocoa powder) and syrups was calculated for prepared beverages (water or milk included) based on suggested recipe declared by the producer (for example, ratio of 1: 6 for syrup and water).

Menus

Using foods for which data have been collected, two daily menus with approximately the same energy value were created with the aim to show differences in price of low i.e. high energy density diet. Low

energy density Menu 1 (Table 3) contains more fresh fruits and vegetables, fruit juices, low fat dairy products and lean meat. In high energy density Menu 2 (Table 4) fresh fruits and vegetables were replaced with fruit compotes and vegetable products, fruit juices were replaced with carbonated soft drinks, low-fat dairy products were replaced with full-fat dairy products, and lean meat was replaced with alternatives that contain more fat.

Results and discussion

In this study negative correlation was found (Pearson correlation r=-0.40, Spearman correlation r=-0.72, p<0.0001) between energy density (kcal/100 g) and food price for 1000 kcal (Fig. 1), which is in accordance with the results of the study conducted by Townsend et al. (2009) that also established negative correlation between energy density and food price.

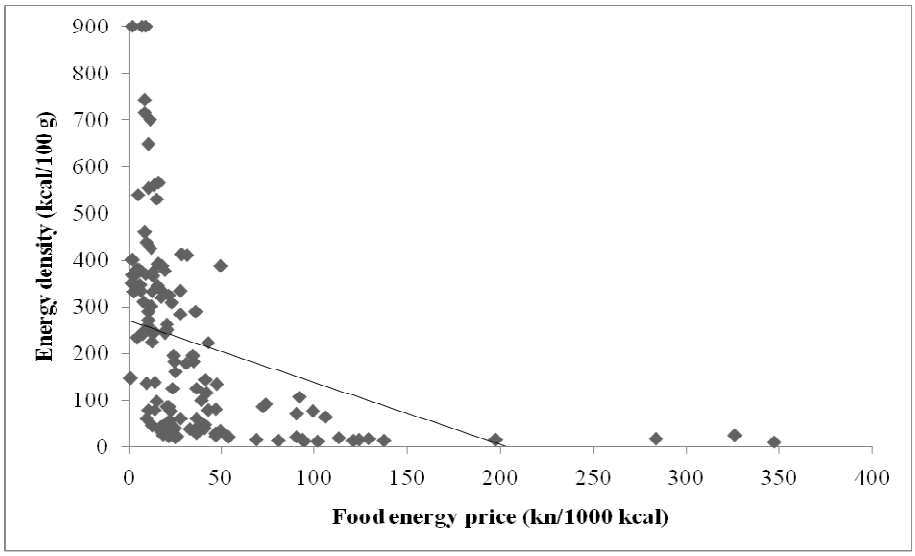

Fig. 1. Energy density (kcal/100 g) is inversely correlated with food energy price (kn/1000 kcal) (Pearson correlation: -0.40, Spearman correlation: -0.72, p<0.0001) (n=137)

Table 1 shows that low energy density foods, such as fruits and vegetables are more expensive than high energy density foods, which contain added sugars and fats. Comparisons between food groups are based on Bonferroni post hoc test after one-way ANOVA. Food energy price was significantly different (p<0.05) between food groups with highest price for vegetable products (159.04 ± 36.18 kn/1000 kcal) and raw vegetables (97.90 ± 50.13 kn/1000 kcal) and lowest for fats (8.49 ± 1.22 kn/1000 kcal) and cereals and products (5.66 ± 0.76 kn/1000 kcal). Price (kn/1000 kcal) for processed and dried fruits is lower than the price of raw fruits. Meat and fish products also have a lower price in comparison to raw foods in this group.

Table 1. Food energy price (kn/1000 kcal) for different food groups ($\bar{x}$ ± SD) (n=137)

Food group	Food energy price (kn/1000 kcal)
Cereals and products (n=14)	5.66 ± 0.76^{a}
Fruit, raw (n=12)	$40.54 \pm 9.85^{a,b,d}$
Fruit products (n=9)	21.34 ± 3.52^{a}
Fruit, dried (n=4)	$24.44 \pm 1.44^{a,c,d}$
Vegetables, raw (n=20)	$97.90 \pm 50.13^{b,c,d,e,f}$
Vegetable products (n=6)	159.04 ± 36.18^{e}
Milk and dairy products (n=19)	25.60 ± 4.52^{a}
Meat, poultry, fish and products, eggs, legumes, nuts (n=35)	32.89 ± 6.54^{a}
Meat, poultry and fish, raw (n=16)	$45.65 \pm 5.36^{a,f}$
Meat, poultry and fish products (n=11)	30.86 ± 9.37^{a}
Sugar, honey and sweets (n=6)	10.64 ± 2.57^{a}
Fats and products (n=8)	8.49 ± 1.22^{a}
Beverages (n=4)	$14.50 \pm 2.91^{a,f}$

Comparisons between food groups are based on Bonferroni post hoc test after one-way ANOVA. Values with different superscript letters are significantly different (p<0.05) from each other.

According to the data, processed vegetables cost more than raw vegetables. The reason for that are included prices for two products (yellow canned pepper and canned mushrooms), which have a much higher price compared to other products.

In general, vegetables have a higher price compared to cereals, meat, milk and dairy products, fats, oils, sweets and drinks. One of the reasons is the fact that sugars and fats, which are high in processed products, are easier to produce, process, transport and store, than are perishable foods such as meat, dairy products, or fresh foods (Drewnowski, 2004) and because of that they cost less.

A diet rich in essential nutrients is important in maintaining and improving health. However, it was shown that the price of low energy density foods rose almost 19.5 % over the two year period from 2004 to 2006, while the price of high energy density foods dropped 1.8 % (Monsivais and Drewnowski, 2007).

The results of this study confirm that the low nutritional quality food costs less and its price is more resistant to inflation. For example, in 2012 price of zucchini had increased by 249.6 % compared to 2008, price of mayonnaise increased by 20.2 %, while the price of olive oil dropped by 33 % (Table 2). Based on paired t-test, average food energy price (kn/1000 kcal) for presented items significantly increased ($p<0.05$) from 2008 to 2012. Variations in the price of olive oil could be explained by different olive yield. For example, in a year with poor olives yield the price of olive oil will increase. The sharp price increase for the low energy density foods suggest that economic factors may pose a barrier to the adoption of more healthful diets and so limit the impact of dietary guidance (Monsivais and Drewnowski, 2007).

Table 2. The comparison of food energy prices (kn/1000 kcal) in year 2008 and 2012

Food group	Year 2008*,#	Year 2012#	Price change 2008 - 2012	
	kn/1000 kcal	kn/1000 kcal	kn/1000 kcal	%
Lettuce	99.58	121.07	21.49	21.6
Zucchini	35.53	124.20	88.67	249.6
Cauliflower	42.48	94.59	52.11	122.7
Cabbage	11.90	21.80	9.90	83.2
Red pepper	87.37	113.30	25.93	29.7
Green beans	84.94	129.59	44.65	52.6
Melon	23.41	47.18	23.77	101.5
Olive oil extra virgin	10.07	6.74	-3.33	-33.0
Butter	6.87	8.43	1.56	22.7
Margarine	2.64	4.80	2.16	81.8
Mayonnaise (with eggs)	6.97	8.38	1.41	20.2

*Data from Koludrović, 2008

#Average of prices from three different purchase sites.

Based on paired t-test, average food energy price (kn/1000 kcal) for presented items significantly increased ($p<0.05$) from 2008 to 2012.

Tables 3 and 4 present two menus, approximately with the same energy value (approximately 1830 kcal), but created of different energy density foods. Energy value refers to foods in their raw form, except for canned tuna. Menu 1 (Table 3) (1824.45 kcal) contains mostly lower energy density foods, as opposed to Menu 2 (Table 4) (1832.00 kcal), which contains mostly high energy density food. According to the prices, it is clear that high energy density Menu 2 costs less (36.28 kn) than the low energy density Menu 1 (50.26 kn).

Healthy diet costs more, i.e. higher prices are associated with less energy and more nutrients. Andrieu et al. (2006) found that consumers who spend the most on food, had lower energy density diets, they consumed less energy but had higher daily intakes of vitamin C (147 %), vitamin D (128 %), vitamin E (114 %), β-carotene (123 %), folate (122 %) and iron (108 %) as compared to those who spent the least money on food. The group with the most money spent on food paid 65 % more than those who spent the least money on food to get 10 % less energy.

The comparison of the Menu 1, composed mainly of low energy density foods (Table 3), and the Menu 2, consisting mainly of high energy density foods (Table 4), with similar energy value, but different energy density, shows that the price of Menu 1 is higher than the price of Menu 2, which is consistent with the results of studies conducted within 78 191 women in the United States (Bernstein et al., 2010) and confirms that the low energy density foods are expensive.

Table 3. Menu 1 (low energy density menu)*

Food	kn/kg	kcal/100 g	kn/1000 kcal	Serving (g)	kcal/serving	kn/serving
Oat flakes	20.98	348	6.03	40	139.20	0.84
Milk 0.5% milk fat	7.46	37	20.15	250	92.50	1.86
White bread	10.29	234	4.40	60	140.40	0.62
Cottage cheese	39.36	100	39.36	80	80.00	3.15
Tomato, red	19.30	14	137.83	100	14.00	1.93
Olive oil extra virgin	60.69	900	6.74	10	90.00	0.61
Orange juice	9.96	46	21.65	250	115.00	2.49
Beef	64.33	183	35.15	100	183.00	6.43
Potato	8.33	79	10.54	100	79.00	0.83
Lettuce	16.95	14	121.07	60	8.40	1.02
Lamb's lettuce	81.60	20	408.00	60	12.00	4.90
Sunflower oil	13.16	900	1.46	10	90.00	0.13
Orange juice	9.96	46	21.65	250	115.00	2.49
Banana	10.96	79	13.87	120	94.80	1.32
Melon	11.32	24	47.18	100	24.00	1.13
Nectarine	8.32	35	23.78	100	35.00	0.83
Almond, dried, peeled	92.29	565	16.34	15	84.75	1.38
Tuna in brine	98.36	107	91.93	80	85.60	7.87
Spaghetti	13.65	378	3.61	60	226.80	0.82
Rucola	81.60	25	326.40	100	25.00	8.16
Olive oil extra virgin	60.69	900	6.74	10	90.00	0.61
Mineral carbonated water	3.53	0	0.00	240	0.00	0.85
Sum				**2195**	**1824.45**	**50.26**

*Energy density = 83.1 kcal/100 g. Price for 1000 kcal = 27.5 kn.

Table 4. Menu 2 (high energy density menu)*

Food	kn/kg	kcal/100 g	kn/1000 kcal	Serving (g)	kcal/serving	kn/serving
Chocolate cereals	70.51	387	18.22	40	154.80	2.82
Milk 3.2% milk fat	5.61	60	9.35	200	120.00	1.12
Bread. white	10.29	234	4.40	60	140.40	0.62
Edam cheese	54.30	345	15.74	60	207.00	3.26
Kranjska sausage	60.81	335	18.15	60	201.00	3.65
Chutney	37.70	80	47.13	10	8.00	0.38
Pork loin central steak	41.11	333	12.35	85	283.05	3.49
Potato	8.33	79	10.54	100	79.00	0.83
Yellow pepper, canned	29.67	15	197.79	85	12.75	2.52
Cola beverage	7.16	42	17.04	200	84.00	1.43
Peach compote	7.16	42	17.04	240	100.80	1.72
Tuna in oil	68.31	195	35.03	65	126.75	4.44
Spaghetti	105.64	289	36.55	80	231.20	8.45
Soft drink	8.48	42	20.19	200	84.00	1.70
Sum				**1480**	**1832.00**	**36.28**

*Energy density = 123.4 kcal/100 g. Price for 1000 kcal = 19.8 kn.

A common perception is that healthy diets cost more, which in turn helps explain why many people do not consume diets that meet current dietary recommendations. However, different approaches to addressing this question, especially in how price is measured, can produce conflicting results (Denny, 2012). Carlson and Frazäo (2012) found that foods low in calories for a given weight appears to have a higher price when the price is measured *per* calories. For example, vegetables, which are generally low in calories, tend to be a relatively expensive source of calories. Less healthy foods, especially those high in saturated fat and added sugar, tend to be high in calories and have a low price *per* calorie. Based on edible weight or average portion size, cereals, vegetables, fruit, and dairy foods are less expensive

than most protein foods and foods high in saturated fat, added sugars, and/or sodium.

Food prices modification could potentially change food choice, thus affecting the diet quality and risk factors for chronic diseases. One way in which to modify food purchases is to change prices through tax policy, subsidy policy, or both on certain products (Epstein et al., 2012). Prices increased by 50 % can result in a reduced energy intake by 16 % (Nederkoorn et al., 2011).

Fletcher et al. (2010) indicated that taxation of soft drinks would result in a reduction of body weight. Some data suggest that taxes, related to food, could avoid those with the lowest incomes (Nnoaham et al., 2009). Tax of 25 % on high energy foods could be a good political method for reducing obesity prevalence (Giesen et al., 2011). Pre-tax simulations, introduced in Denmark, predict that the health tax on saturated fat, i.e. food which contains 2.3 g of saturated fat *per* 100 g, will give rise to a reduction in the consumption of saturated fat of approximately 8 % (Smed, 2012).

Conclusions

It seems that eating healthier costs more. Negative correlation was observed between energy density and food price, which means that high energy dense food, such as food rich in fats and added sugars, costs more than low energy dense food (fresh fruits and vegetables).

In general, food prices in 2012, compared to those in 2008, are higher more than 20 %. However, high energy density food is more resistant to inflation than low energy density food. Comparing the two daily menus of approximately the same energy value and different energy density, it was found that the low energy density menu is much more expensive. Although food prices affects everyone, food prices as a barrier to change eating habits still mostly affects low-income households.

Better understanding of the relationship between obesity, diet quality and prices can help to improve the nutritional strategies for the prevention of obesity and related chronic diseases. Focusing on how much balanced diet costs is a good start. It is necessary to monitor food prices and affordability of food with higher nutrient density. Further research should be conducted to identify the ideal combination of interventions to maximize the effect on diet quality where the possible interventions include food prices modification and emphasizing the affordable prices of key nutrients in vegetables and fruits to increase their consumption, through tax policy and/or subsidy policy on certain products.

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