

## Selected Fruits and Vegetables: Comparison of Nutritional Value and Affordability

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### Abstract

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We compared subgroups of fruit and vegetables which provide the best nutritional value per unit cost. For this purpose, nutrient adequacy score and nutrient density score, based on the content of vitamins A, C, E, folate, thiamine, riboflavin, calcium, iron, potassium and magnesium, were calculated and subsequently complemented by food prices. The study was focused on elderly people over 65 years. The nutrient density score for vegetables was found significantly higher than that for fruit ( $P < 0.001$ ), which implies that vegetables provide a higher amount of nutrients per energy unit. The highest nutrient-to-price ratio was observed for carrot, savoy cabbage, head cabbage, pepper, kohlrabi, green peas, and potatoes. Our results can help consumers identify affordable nutrient-rich types of fruit and vegetables and maximise the nutrient-to-calorie ratio.

**Keywords:** dietary cost; elderly people; nutrient profile; nutrient score

Fruit and vegetables (F&V) provide essential components of a balanced diet and are ranked as nutrient-dense foods. The term “nutrient-dense” indicates that these foods provide nutrients (e.g. potassium, magnesium, vitamin C, vitamin A, folate), dietary fibre and other bioactive compounds with potentially positive health effects and relatively few calories. Low energy content of nutrient-dense food facilitates maintaining a healthy weight (USDA 2010). A higher consumption of F&V can be associated with a lower risk of some chronic diseases (EFSA 2008), especially cardiovascular diseases, including heart attack and stroke. Some F&V may have a protective effect against certain types of cancer (USDA 2010). The effect cannot be easily explained on the basis of their nutrient content. Intakes of F&V are low in many EU countries (EFSA 2008). An increase of F&V consumption would be appropriate especially for elderly people because

they are at greater risk for nutritional deficiencies as compared with younger adults (SCHRÖDER *et al.* 2008). Daily intake of 600 g of various F&V is recommended by the Czech Nutrition Society, including heat-treated vegetables (DOSTÁLOVÁ *et al.* 2012). Estimated average F&V consumption was 274 and 317 g/day for Czech men and women over 60 years in 2004, respectively (excluding potatoes) (RUPRICH *et al.* 2006).

Besides taste and convenience, food cost is the most consistently noted barrier to adequate consumption of F&V (DARMON *et al.* 2005), not only in higher quantities but also in greater variety (PEARSON *et al.* 2014). Fresh F&V (especially dark green vegetables) are more likely to be consumed by groups of the higher socio-economic status due to association with relatively high price for energy unit unlike fats and sweets (CASSADY *et al.* 2007). On the other hand, previous studies have shown that some vegetables

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are low-cost sources of several nutrients, such as potassium, vitamin C and also fibre (DREWNOWSKI & REHM 2013).

Nutrient profiling means categorising foods based on their nutrient content. Models calculate the percentage requirements for selected nutrients in foods relative to the dietary energy that the foods provide (Drewnowski 2009). Nutrient profiles can be formulated specifically for food categories (EFSA 2008). The aim of this study was to establish nutrient adequacy and nutrient density scores for F&V commonly consumed in the Czech Republic and to identify species which provide the best nutritional value per unit cost. These could help consumers to recognise affordable nutrient-rich F&V.

## MATERIAL AND METHODS

Our approach is based on evaluating the intake of selected nutrients relative to the dietary reference values (DRV) within a single food group. Selected F&V were ranked according to their nutrient adequacy score and nutrient density score. Nutrient profiling methods were combined with food price data in order to identify F&V which provide a substantial amount of nutrients in relation to the price and energy content.

**Selected fruits and vegetables.** Fruits ( $n = 28$ ) and vegetables ( $n = 28$ ) commonly consumed in the Czech Republic were included in the study (RUPRICH *et al.* 2006), regardless of the varieties. Excluded were vegetables which are typically consumed in small serving sizes (with the exception of garlic). Potatoes were included in the vegetable group, although they are typically assigned to the starchy tubers group. Processed products like juices, canned fruit etc. were excluded. Nutritional values in fresh state were used for fruits. For vegetables that are not commonly consumed in fresh state nutritional values for cooked vegetables were used.

**Selection of nutrients.** Ten nutrients (vitamin A, C, E, folate, thiamine, riboflavin, calcium, iron, potassium, and magnesium) were selected according to the interest in public health based on Czech food consumption data (RUPRICH *et al.* 2006).

**Nutrient composition data.** A compiled table of nutritional values based on available data from various countries was used. The preferred data were of Czech (On-line Czech Food Composition Database v. 3.12, <http://www.czfcdp.cz>), Slovak (VÚP SK) and

lastly German origin (SOUCI *et al.* 2008). Nutrient values were provided per 100 g of food product, edible portion (e.p.) adjusted for preparation and waste.

**Food prices data.** F&V prices were collected in 4 dominant food store chains in Brno: Tesco, Albert, Kaufland, Globus (market share 13.4–25.4%) during 4 periods (February, May, July, and September) in 2013 (INCOMA GfK 2011). Retail prices, obtained in CZK/kg or unit of food “as purchased”, were adjusted for prices per 100 g e.p. The lowest price of a given item in each retail shop, regardless of the variety, was taken into account. The data were processed as the mean of 4 values representing data obtained from 4 retail shops for each time period individually. Average price of 4 time periods was subsequently calculated and used for graphical display.

**Nutrient adequacy score (NAS) and nutrient density score (NDS).** Following the method described by DARMON *et al.* (2005), NAS calculation was based on the mean of percent DRV for 10 selected nutrients, as provided by 100 g e.p. of food item:  $NAS = [\sum (\text{Nutrient}_{1-10} / \text{DRV}_{1-10}) \times 100] / 10$ . Dividing the

Table 1. Twenty fruits and vegetables with the highest nutrient adequacy score (NAS) and nutrient density score (NDS)

Foods	NAS	Foods	NDS
Spinach*	19.39	spinach*	24.55
Savoy cabbage*	18.33	savoy cabbage*	18.34
Broccoli*	16.86	pepper	15.29
Pepper	16.12	radishes	14.52
Kiwifruit	13.36	lettuce	13.02
Currant	13.05	broccoli*	11.55
Carrot*	12.47	head cabbage	11.20
Leek	12.39	carrot*	10.66
Kohlrabi	11.12	cauliflower*	10.21
Blueberries	10.93	kohlrabi	9.75
Parsley*	10.32	leek	9.12
Strawberries	9.93	cucumber	8.81
Cauliflower*	9.80	tomatoes	8.25
Green peas*	9.78	currant	8.16
Oranges	9.62	white radish	7.33
Mango	9.33	pumpkin*	7.18
Garlic	8.92	courgette*	7.16
Lemon	8.88	head cabbage*	6.69
Lettuce	8.46	pattypan*	6.32
Raspberries	8.29	blueberries	6.32

\*cooked

NAS by the energy density of the food yielded a base for determination of nutrient density score (NDS):  $NDS = (NAS/energy\ density) \times 100$ . Energy density was defined as the amount of available energy per unit weight of food (in kJ/100 g e.p.). Dividing NAS by the mean price per 100 g e.p. (in CZK) yielded a nutrient-to-price ratio (N-P ratio):  $N-P\ ratio = NAS/price$ . In order to avoid overestimation caused by the fact that certain foods are excellent sources of a single nutrient, present in a large amount, but do not contain a wide range of key nutrients, the maximum percent DRV of the given nutrients was capped at 100%.

**Dietary reference values (DRV).** DACH-reference values (SPV 2011), often used also in the Czech Republic, were applied for the NAS calculation in a population group under investigation: elderly people over 65 years.

**Statistical analyses.** All analyses were performed using the Statistica v. 12 software (Statsoft Inc., Tulsa, USA). Differences in NAS, NDS, and N-P ratio between groups were established using *t*-test (with the Welch correction) after log transformation. Scatterplots and Pearson correlation coefficient were used to show a relation between NAS and NDS and between NAS and price. An  $\alpha$ -level of 0.05 was used to determine statistical significance.

## RESULTS AND DISCUSSION

Our results showed that the nutritive value can vary widely within the F&V group. The best nutritional value based on the calculation of NAS (per 100 g e.p.) is provided by the following F&V types: spinach, savoy cabbage, broccoli, pepper, kiwifruit, berries, carrot, leek, kohlrabi, parsley, etc. (Table 1). However, the calculation based on 100 kJ (NDS) better reflects the nutrient density of foods, defined as the ratio of nutrients to energy density (DREWNOWSKI 2009).

When comparing the use of NDS and NAS, a difference between these two values (NDS–NAS) of individual items is significantly higher for vegetables than for fruit ( $P < 0.001$ ), especially for the following items: radishes, cucumber, lettuce, and Chinese cabbage. It is caused by the high nutrient content in relation to low energy density. Nevertheless, NAS and NDS were positively correlated ( $r = 0.7574$ ).

The vegetable group was found to have higher NAS ( $P = 0.05$ ) and especially significantly higher NDS ( $P < 0.001$ ) compared to the fruit group. In order to ensure a high supply of nutrients and a low

energy intake, consumption of vegetables should be recommended before fruit.

Foods which are characterised by a high nutritional value are not necessarily the best cost-effective option (DREWNOWSKI 2010). Within the food group, subgroups can also differ widely in terms of cost per MJ. Dried fruits seem less expensive as a source of energy than fresh F&V but their nutrient densities are also lower (MAILLOT *et al.* 2007). As published by CASSADY *et al.* (2007), in the USA the highest average price per serving was observed for fruits and dark green vegetables. The subgroups with the lowest price per serving were oranges and starchy vegetables. DREWNOWSKI (2010) found that in the USA the highest scoring foods were citrus fruits and juices followed by potatoes. More recently, white potatoes, beans, carrots, and some dark green vegetables were identified as both affordable and nutrient-dense. Of the vegetables with the highest affordability scores, white potatoes and carrots had the highest frequency of use in the USA (DREWNOWSKI & REHM 2013). According to our results, the N-P ratio was significantly higher for vegetables than for fruits ( $P < 0.001$ ). Figure 1 shows F&V with a higher N-P ratio than the others.

As shown in Figure 2, in the area with high NAS and relatively low price (quadrant I – divided according to medians) are located the following items: savoy cabbage, pepper, carrot, kohlrabi, parsley, cauliflower, green peas (frozen), orange, Chinese cabbage, tomatoes, courgette, banana, grapefruit, and tangerine. High price and relatively low NAS

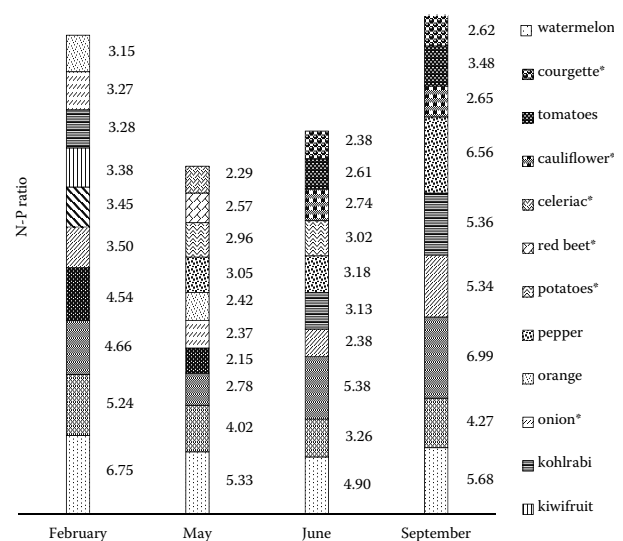


Figure 1. Ten fruits and vegetables with the highest nutrient-to-price ratio (N-P ratio) for given months in 2013 (\*cooked)

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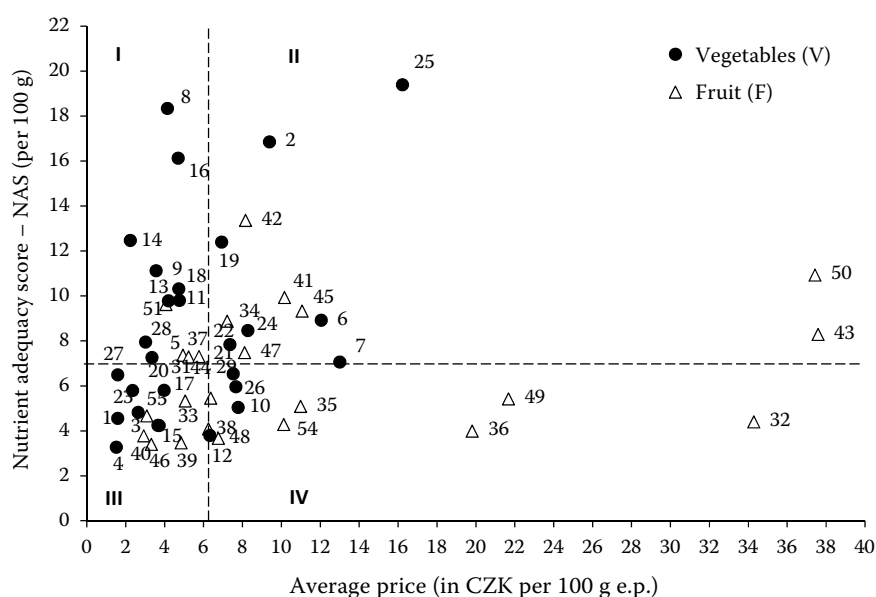


Figure 2. Relation between NAS and average price (in CZK)

1 – potatoes\*, 2 – broccoli\*, 3 – celeriac\*, 4 – onion\*, 5 – courgette\*, 6 – garlic, 7 – green beans (pods)\*, 8 – savoy cabbage\*, 9 – kohlrabi, 10 – sweetcorn\*, 11 – cauliflower\*, 12 – aubergine\*, 13 – green peas\*, 14 – carrot\*, 15 – cucumber, 16 – pepper, 17 – pattypan\*, 18 – parsley\*, 19 – leek, 20 – tomatoes, 21 – radish, 22 – white radish, 23 – red beet\*, 24 – lettuce, 25 – spinach\*, 26 – pumpkin\*, 27 – head cabbage\*, 28 – Chinese cabbage, 29 – pineapple, 30 – gooseberry, 31 – banana, 32 – blueberry, 33 – peach, 34 – lemon, 35 – date, 36 – fig, 37 – grapefruit, 38 – grape, 39 – pear, 40 – apple, 41 – strawberry, 42 – kiwifruit, 43 – raspberry, 44 – tangerine, 45 – mango, 46 – watermelon, 47 – apricot, 48 – nectarine, 49 – olive, 50 – blackberry, 51 – orange, 52 – currant, 53 – greengage, 54 – cherry, 55 – plum, 56 – sour cherry (\*cooked); missing numbers indicate the unavailability of items on the market

(quadrant IV) were observed for blueberry, olive, fig, cherry, etc.

This study has some limitations which are worth noting. NAS and subsequent calculations were limited to 10 selected vitamins and minerals. The results may vary if different nutrients are used. Other substances, which can also be important constituents, were not included, e.g. phytochemicals like polyphenols, carotenoids or trace elements. This is due to a lack of compositional data and DRV. If dietary fibre or other bioactive substances are also included, some F&V will presumably obtain a higher score (PENNINGTON *et al.* 2007).

In this study, unweighted score was used; each nutrient was assigned the same importance. However, key nutrients can be assigned higher weights based on their bioavailability or distribution in the food supply. Some nutrients are widely distributed whereas others are limited to certain food sources (DREWNOWSKI & FULGONI 2008).

Furthermore, food prices are not based on national data. Collection of the data was limited to shops located in Brno. On the other hand, selected shops represent the dominant food chains in the Czech Republic. It is

also necessary to mention the fact that not all F&V are acceptable for all individuals. More frequent constraints can be expected for elderly people.

## CONCLUSION

The intent of nutrient scoring was to evaluate the intake of selected nutrients from F&V relative to DRV. Nutrient-profiling systems, when complemented by food-price data, may assist consumers in identifying foods that are both affordable and nutrient-rich. Improving the diet quality is not necessarily associated with increased diet costs.

Our results indicate that in the Czech Republic carrot, savoy cabbage, head cabbage, pepper, kohlrabi, peas and potatoes provide the best nutritional value with respect to the price (focused on elderly people over 65 years). Statistical comparison of NDS between fruit and vegetables confirmed that vegetables provide a higher amount of studied nutrients per energy unit ( $P < 0.001$ ). This is important for prevention of micronutrient deficiency, especially

for elderly people. Elderly people should consume the nutrient-dense foods to a larger extent due to a decline of energy intake depending on age. Similarly, the nutrient density approach can be applied to weight control (DREWNOWSKI *et al.* 2005). Nevertheless, not all affordable nutrient dense F&V are a part of mainstream eating habits (DREWNOWSKI & REHM 2013). For future research, we plan to conduct a survey among elderly people in order to provide information which types of F&V are not acceptable for people over 65 years.

Although the presented results indicate F&V which are both nutrient-dense and more affordable than others, a high priority is placed on maintaining diversity in consumed F&V. Various types can provide many chemical substances of diverse origin with beneficial health effects (EFSA 2008).

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