Impact of organic fertilizers on total antioxidant capacity in head cabbage

P. Bímová, R. Pokluda

Faculty of Horticulture, Mendel University of Agriculture and Forestry in Brno, Lednice, Czech Republic

ABSTRACT: In recent years, the agri-food sector and consumers have begun to look at food not only for basic nutrition, but also for health benefits. The purpose of this study was to investigate the variations in the total antioxidant capacity (TAC) in head cabbage according to the used type of fertilizer. Commercial brands of alternative, organic fertilizers were compared with conventional, mineral fertilizers in culture of head cabbage. There were seven different treatments: Agormin, Agro, farmyard manure, horticultural compost, Dvorecký agroferm, mineral fertilizer, and an unfertilized control. All the treatments assured approximately the same level of nutrients. The level of TAC was measured by the FRAP assay and the effect of storage on TAC was also studied. Average value of TAC in fresh cabbage was 236 ± 60 mg GA/100 g in the year 2005 and 295 ± 27 mg GA/100 g in the year 2006. The TAC value decreased in the course of storage. The average value of TAC after a five-month period of storage was 56 ± 18 mg GA/100 g in the year 2005 and 33 ± 5 mg GA/100 g in the year 2006. This study shows that alternative, organic fertilizers have similar or even better qualities than farmyard manure and that they can contribute to the improvement of nutritional values of vegetable.

Keywords: alternative organic fertilizer; cabbage; FRAP; storage; total antioxidant capacity

In recent years, the role of natural dietary antioxidants in disease prevention has been the focus of much investigation. A literature search revealed that the number of publications on antioxidants and oxidative stress nearly quadrupled in the past decade – from 1,684 in 1993 to 6,510 in 2003 (Huang et al. 2005). Antioxidants inhibit free radical reactions, and may therefore protect cells against oxidative damage. Fruit, vegetables, nuts and seeds, provide a rich source of antioxidant vitamins, and other phytochemicals with antioxidant characteristics. The antioxidant content of fruit and vegetables may contribute to the protection against diseases. Plant foods contain many different classes and types of antioxidants, and thus knowledge of their total antioxidant capacity (TAC), which is the cumulative capacity of food components to scavenge free radicals, would be useful for epidemiologic purposes (Kurilich et al. 2002; Lindsay, Astley 2002; Pellegrini 2003). Cruciferous vegetables, including cabbage (*Brassica oleracea* convar. *capitata*), have a high nutritional value and contain organosulphur phytochemicals that increase their antioxidant capacity, which may have anticarcinogenic effects (Kurilich et al. 1999; Kim et al. 2004).

Head cabbage is the most important field vegetable crop in the Czech Republic, as well as in many other countries. Annually, around 1,310 ha of head cabbage are cultivated in Czech Republic and come second after onions (Buchtová 2006; Roy et al. 2007). Cultivation of cabbage needs fertilizing by farmyard manure (Vogel et al. 1996; Murison, Napier 2006; Din et al. 2007). Farmyard manure is a natural source of organic matter and vegetable production requires seasonal supply applications of organic matter (Bunting 1965). However, as a lot of farms specialize in vegetable production these days, they have no animals, and so traditional farmyard manure is consequently in short supply. On the other hand, the farms specialized in rearing livestock have the opposite problem, namely, an abundance of manure which is difficult to dispose of. This surplus farmyard manure can be returned to the soil by processing it to make an organic fertilizer by aerobic fermentation and drying (Debosz et al. 2002).

Supported by the Ministry of Agriculture of the Czech Republic, Project No. QF 4195.

The aim of this study was to observe the effect of these alternative organic fertilizers and storage on the total antioxidant capacity (TAC) of head cabbage. The average value of TAC presented by Zloch et al. (2004) in head cabbage was 97 mg GA/100 g, while that published by Pellegrini et al. (2003) was 5.79 mmol Fe^{2+}/kg f.m. The evaluation of fruit and vegetable antioxidant capacity is not an easy task, as many methods can be used to determine this activity, and substrates, conditions, analytical methods, concentrations and units can affect the estimated activity (Gil et al. 2002).

Table 1. Results of soil analysis

Nutrient reserve	2005	2006
pH	7.5	6.8
Humus	4.2%	4.5%
N_{min}	below 15 mg/kg	below 15 mg/kg
P	low	high
K	suitable to good	good
Mg	low	very high
Ca	very high	very high

MATERIAL AND METHOD

The two-year experiment took place at the Faculty of Horticulture of Mendel University of Agriculture and Forestry in Brno, Lednice in 2005 and 2006. Within the experiment, 7 following treatments were established:

- Agormin (AGRO CS, a. s., CZ) – an organo-mineral fertilizer, made from peat with added basic macroelements (3.7% N; 1.4% P; 7.1% K),
- Agro (MeMon B.V., NL) – an organic fertilizer, made from dehydrated poultry bedding and molasses (3.5% N; 1.5% P; 7% K),
- Dvorecký agroferm (Agropodnik Dvorce, a. s., CZ) – an organic fertilizer, made from fermented and dehydrated farmyard manure (1.6% N; 0.6% P; 1.0% K),
- horticultural compost (AGRO CS, a. s., CZ) – an organic fertilizer, made from plant waste with added dolomitic calcite (1.0% N; 0.4% P; 1.7% K),
- conventional farmyard manure (local source – Lednice, CZ) – treated mixture of bedding, stiff and liquid feces of livestock (3.0% N; 1.4% P; 2.7% K),
- conventional mineral fertilizer (AGRO CS, a. s., CZ) – ammonium sulphate (21% N), potassium sulphate (18% P), superphosphate (50% K),
- control – unfertilized.

Each treatment was carried out with three replicates. The application rates were in accordance with the manufacturers' guidelines (Agormin 2.5 t/ha; Agro 1 t/ha; Dvorecký agroferm 0.8–1 t/ha; compost 30 t/ha) and in the case of farmyard manure 55 t/ha was applied as recommended by Malý et al. (1998). All variants, except the control one, were fertilized on the same level of nutrients according to the soil analysis (Table 1) and supposed the yield of 50 t/ha. The rates of nutrients required for 1 ton of cabbage are as follows: 3.57 kg N; 0.57 kg P; 3.57 kg K; 2.86 kg Ca; 0.57 kg Mg and 1.1 kg S. Corrections were made depending on the organic fertilizer, the preceding crop and the content of nutrients in the soil according to Hlušek (1996).

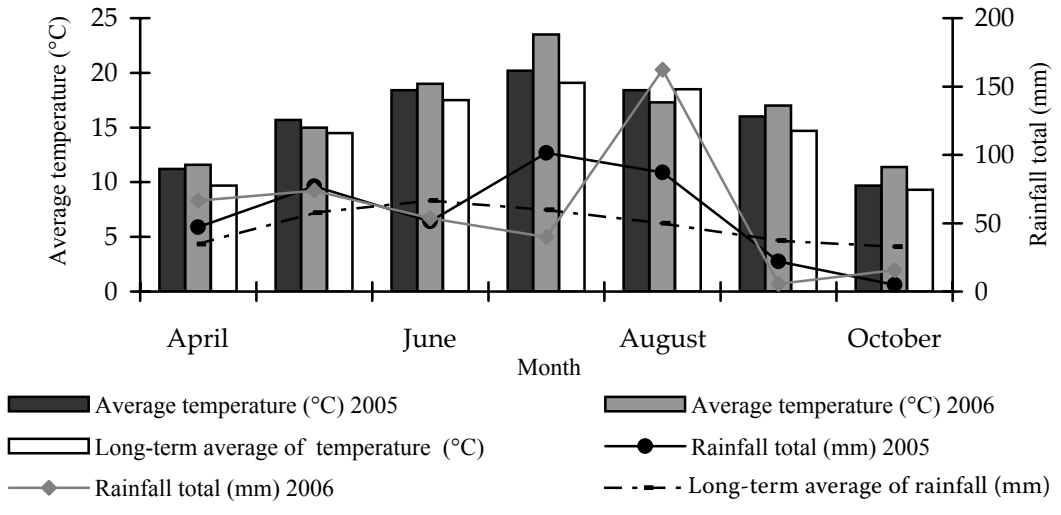

Fig. 1. Climatic conditions

The cultivar of head cabbage used was TRVALO F1 (Semo Smržice, CZ), which is acceptable for long-term storage. Harvesting was done on October 11 2005 and on October 20 2006 and the heads were classified as Grade I or II quality in accordance with the local norm ČSN 46 3113 (UNECE STANDARD FFV-09). The climatic conditions during the growing season in both years compared with long-term averages are presented in Fig. 1. Analyses were done from average samples by measuring then immediately after harvest and after 5-month period of storage. Cabbage was stored immediately after harvest on October 11 2005 and it was finished on March 20 2006. The following year it was stored from October 20 2006 to March 6 2007. Cabbage was stored at 0°C with 90–95% RH. Average sample was composed from 3 cabbage heads without stalks. Total antioxidant capacity (TAC) was assessed by the FRAP (Ferric Reduction Ability of Plasma) assay according to Zloch et al. (2004) using a JENWAY 6100 spectrophotometer. The results were expressed as mg of gallic acid equivalents per 100 g of fresh matter (mg GA/100 g). All results were processed by the ANOVA and Tukey's test using the statistical program Unistat 5.1 (Unistat, USA) at the probability of 95%.

RESULTS AND DISCUSSION

The average value of TAC immediately after harvest was 236 ± 60 mg GA/100 g in the year 2005 and 295 ± 27 mg GA/100 g in the year 2006. The average value of TAC after 5-month period of storage was 56 ± 18 mg GA/100 g in the year 2005 and 33 ± 5 mg GA/100 g in the year 2006. The mean values of TAC in cabbage heads for each treatment are shown in Table 2. The results show a threefold higher value of TAC in winter cabbage in comparison with data mentioned by Zloch et al. (2004). The highest mean levels of TAC were observed in Dvorecký agroferm, and were significantly higher than those of the mineral fertilizer treatment in 2005. There were no significant differences between the treatments in the levels of TAC in the year 2006; the highest value of TAC was however found again in Dvorecký agroferm. According to Ismail et al. (2004) the variation between years could be due to environmental

Table 2. Mean value of TAC in cabbage in the years 2005 and 2006

Fertilizer	TAC after harvest (mg GA/100 g)	TAC after storage (mg GA/100 g)	Storage losses (%)
Year 2005			
Agormin	292 ± 16 ab	71 ± 2ab	75.6
Agro	212 ± 43 ab	43 ± 6ab	79.6
Compost	201 ± 34 ab	48 ± 22ab	74.2
Control	233 ± 32 ab	49 ± 23ab	79.6
Dvorecký agroferm	314 ± 30 b	77 ± 5b	75.3
Farmyard manure	211 ± 65 ab	63 ± 12ab	69.1
Mineral fertilizer	186 ± 73 a	38 ± 3a	76.7
Mean	236 ± 60	56 ± 18	76.3
Year 2006			
Agormin	292 ± 21a	34 ± 4 abc	88.5
Agro	295 ± 19a	27 ± 3 a	90.7
Compost	284 ± 22a	39 ± 1 c	86.3
Control	299 ± 27a	37 ± 1 bc	87.5
Dvorecký agroferm	316 ± 52a	34 ± 5 abc	89.3
Farmyard manure	296 ± 32a	30 ± 1 ab	89.8
Mineral fertilizer	281 ± 5a	31 ± 3 abc	89.1
Mean	295 ± 27	33 ± 5	88.8

Means are followed by standard deviation. Different letters indicate significant differences at $P \leq 0.05$ (Tukey's HSD test)

Table 3. Effect of fertilization treatment on the value of TAC in 2 years

Treatment	After harvest	After storage	Summary
Agormin	7	5	12
Agro	8	13	21
Control	5	6	11
Dvorecký agroferm	2	5	7
Farmyard manure	8	9	17
Mineral fertilizer	14	12	26
Compost	12	6	18

factors, such as a climatic growth conditions. The different climatic conditions during years 2005 and 2006 are presented in Fig. 1.

Results of alternative organic fertilizers (Dvorecký agroferm, Agormin) showed minimal variability in values of TAC within two years in spite of very different climatic conditions during both years, whereas mineral fertilizer, compost, Agro and farmyard manure were much more influenced by climatic conditions.

The effect of storage on TAC was significant in both years. Statistically significant higher value of TAC was found immediately after harvest. The value of TAC decreased in the course of storage. In compliance with the results of Walkowiak-Tomczak (2007), storage and processing antioxidant capacity decreased. The average loss of TAC after storage period was 76.3% in the year 2005 and 88.8% in the year 2006. The lowest loss was found with farmyard manure in the year 2005 and the highest with Agro in 2006.

Many experiments have shown that cabbage gives a good response to manure and most of earlier experiments indicate a superiority of manure over commercial fertilizers (Din et al. 2007). The studies of Abou El-Magd et al. (2006) and Toor et al. (2006) are cited in support of nutrition benefit of organic fertilizers. According to Toor et al. (2006), organic fertilizers may increase the content of ascorbic acid and total phenolics in tomato. Abou El-Magd (2006) showed that organic fertilizers could be followed for producing high yields of broccoli with high quality of heads.

A simplified evaluation of results is presented in Table 3, showing the order of treatments according to the value of TAC. There were 7 different treatments, and consequently, the treatment with the highest value was classified as number 1 and the treatment with the lowest value of TAC has number 7. A theoretical value of the best treatment is 2 and the worst is 14, since biennial records are presented. This table shows that the best treatment was Dvorecký agroferm, whereas the worst was mineral fertilizer. Farmyard manure was worse than the control; other alternative organic fertilizers, namely Agormin, showed similar or better results than farmyard manure.

CONCLUSION

The results of this study indicate that different fertilizers influenced the TAC and thus affected the nutritional values of vegetables. Alternative organic fertilizers can positively influence TAC in vegetable; their effect to nutritional value can be also positive. Results show that storage significantly reduced the TAC value. Alternative organic fertilizers have similar or even better qualities than farmyard manure and so they can improve the nutritional value of vegetable production.

References

ABOU EL-MAGD M.M., EL-BASSIONY A.M., FAWZY Z.F., 2006. Effect of organic manure with or without chemical fertilizers on growth, yield and quality of some varieties of broccoli plants. Journal of Applied Sciences Research, *2*: 791–798.

BUCHTOVÁ I., 2006. Situační a výhledová zpráva zelenina. Praha, MZe ČR.

BUNTING A.H., 1965. Effects of organic manures on soils and crops. Proceedings of the Nutrition Society, *24*: 29–38.

DEBOSZ K. et al., 2002. Evaluating effects of sewage sludge and household compost on soil physical, chemical and microbiological properties. Applied Soil Ecology, *9*: 237–248.

DIN M., QASIM M., ALAM M., 2007. Effect of different levels of N, P and K on the growth and yield of cabbage. Journal of Agricultural Research, *45*: 171–176.

GIL M.I. et al., 2002. Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine,

peach, and plum cultivars from California. Journal of Agricultural and Food Chemistry, *50*: 4976–4982, 5057.
HLUŠEK J., 1996. Základy výživy a hnojení zeleniny a ovocných kultur. Praha, MZe ČR.
HUANG D., OU B., PRIOR R.L., 2005. The chemistry behind antioxidant capacity assays. Journal of Agricultural and Food Chemistry, *53*: 1841–1856.
ISMAIL A., MARJAN Z.M., FOONG C.W., 2004. Total antioxidant activity and phenolic content in selected vegetable. Food Chemistry, *87*: 581–586.
KIM D.O., PADILLA-ZAKOUR O.I., GRIFFITHS P.D., 2004. Flavonoids and antioxidant capacity of various cabbage genotypes at juvenile stage. Journal of Food Science, *69*: C685–C689.
KURILICH A.C. et al., 1999. Antioxidant capacity of different broccoli (*Brassica oleracea*) genotypes using the oxygen radical absorbance capacity (ORAC) assay. Journal of Agricultural and Food Chemistry, *47*: 1576–1581.
KURILICH A.C. et al., 2002. Carotene, tocopherol, and ascorbate contents in subspecies of *Brassica oleracea*. Journal of Agricultural and Food Chemistry, *50*: 5053–5057.
LINDSAY D.G., ASTLEY S.B., 2002. European research on the functional effects of dietary antioxidants – EUROFEDA. Molecular Aspects of Medicine, *23*: 1–38.
MALÝ I. et al., 1998. Polní zelinářství. Praha, Agrospoj.
MURISON J., NAPIER T., 2006. Gabbage growing. Primefact 90. NSW DPI, State of New South Wales: 7.
PELLEGRINI N. et al., 2003. Total assay antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different *in vitro*. Journal of Nutrition, *133*: 2812–2819.
ROY M.K. et al., 2007. Antioxidant potential, anti-proliferative activities, and phenolic content in water-soluble fractions of some commonly consumed vegetables: Effects of thermal treatment. Food Chemistry, *103*: 106–114.
TOOR R.K. et al., 2006. Influence of different types of fertilisers on the major antioxidant components of tomatoes. Journal of Food Composition and Analysis, *19*: 20–27.
VOGEL G., HARTMANN H.D., KRAHNSTÖVER K., 1996. Handbuch des speziellen Gemüsebaues. Stuttgart, Verlag Eugen Ulmer: 1127.
WALKOWIAK-TOMCZAK D., 2007. Changes in antioxidant activity of black chokeberry juice concentrate solution during storage. Acta Scientiarum Polonorum, *6*: 49–55.
ZLOCH Z., ČELAKOVSKÝ J., AUJEZDSKÁ A., 2004. Stanovení obsahu polyfenolů a celkové antioxidační kapacity v potravinách rostlinného původu (on-line). Ústav hygieny Lékařské fakulty UK, Plzeň. Cited [2004-12-10]. http://www.danone-institut.cz/files/2004.04/.

Received for publication March 19, 2008
Accepted after corrections September 12, 2008

Vliv organických hnojiv na celkovou antioxidační kapacitu v hlávkovém zelí

ABSTRAKT: V posledních letech se zemědělci i spotřebitelé soustřeďují na potraviny nejen jako na základní zdroje výživy, ale i jako na zdroje zdraví prospěšných látek. Záměrem studie bylo prozkoumat vliv různých hnojiv na celkovou antioxidační kapacitu (TAC) v hlávkovém zelí. Komerční produkty alternativních organických hnojiv byly v kultuře hlávkového zelí srovnávány s konvenčními, průmyslovými hnojivy. Bylo sledováno sedm variant výživy: Agormin, Agro, chlévský hnůj, zahradnický kompost, Dvorecký agroferm, minerální hnojivo a nehnojená kontrola. Všechny varianty byly vyhnojeny na srovnatelnou úroveň živin. Pro měření TAC byla použita metoda FRAP. V pokusu byl sledován vliv skladování. Průměrná hodnota TAC v čerstvém zelí byla 236 ± 60 mg GA/100 g v roce 2005 a 295 ± 27 mg GA/100 g v roce 2006. Během skladování došlo k poklesu TAC. Průměrná hodnota TAC po pěti měsících skladování byla 56 ± 18 mg GA/100 g v roce 2005 a 33 ± 5 mg GA/100 g v roce 2006. Studie ukazuje, že alternativní, organická hnojiva mají podobné nebo dokonce lepší vlastnosti než chlévský hnůj a mohou tak přispět ke zlepšení nutriční hodnoty zelenin.

Klíčová slova: alternativní organická hnojiva; zelí; FRAP; skladování; celková antioxidační kapacita

Corresponding author:

Ing. Pavla Bímová, Mendelova zemědělská a lesnická univerzita v Brně, Zahradnická fakulta, Valtická 337, 691 44 Lednice, Česká republika
tel.: + 420 519 367 236, fax: + 420 519 367 222, e-mail: mapab@atlas.cz