ELSEVIER

0308-8146(95)00218-9

*Food Chemistry*, Vol. 57, No. 2, pp. 267–270, 1996

0308-8146/96 $15.00+.00

# Effects of level of nitrogen fertilizer, processing conditions and period of storage of frozen broccoli and cauliflower on vitamin C retention

**Z. Lisiewska* & W. Kmiecik**

*Department of Raw Materials and Processing of Fruit and Vegetables, Agriculture University, 3 Podluzna Street, Krakow, Poland*

(Received 9 August 1995; accepted 18 October 1995)

Directly after harvesting, broccoli contained 116.3–116.4 mg of vitamin C in 100 g of fresh matter, and cauliflower contained 60.5–64.7 mg. Increasing the amount of nitrogen fertilizer from 80 to 120 kg N $ha^{-1}$ decreased the content of vitamin C only in cauliflower (by 7%), at the same time raising the level of nitrates by 44% in broccoli and by 33% in cauliflower. During the course of processing, the greatest losses in vitamin C content occurred during blanching: in broccoli by 41–42% and in cauliflower by 28–32%. Freezing resulted in little change of the vitamin C content, which was reduced by 15–18% in broccoli and by 6–13% in cauliflower during freeze-storage. After 12 months of storage, the level of vitamin C was 54.9–57.4 mg per 100 g of frozen product in broccoli and 38.5–41.9 mg per 100 g in cauliflower, being slightly higher at a storage temperature of −30°C than at −20°C. Copyright © 1996 Elsevier Science Ltd

## INTRODUCTION

The consumption of cruciferous vegetables, especially cabbage, has a long tradition in Poland owing to their high storage and pickling qualities. The consumption of cauliflower and especially broccoli is much lower and in general limited to the growing season, even though these two species are superior to cabbage in their nutritive value and vitamin C content. The importance of these vegetables in contributing to vitamin C in the diet is indisputable (Block & Langseth, 1994; Fitch, 1994).

In Poland the rapid development of the freezing industry has allowed the introduction of the above-mentioned species into the year-round diet. It is important, however, to supply the consumer with products that are not only of good sensory quality but are also of high nutritive value, properties that are undoubtedly affected by agrotechnical and technological factors. Among the former, the addition of high levels of nitrogen is known to increase the yield of the two species (Maurya *et al.*, 1992; Nilsson, 1980; Tremblay, 1989), but at the same time this may cause excessive accumulation of nitrates (Greenwood & Hunt, 1986; Raber & Kunsch, 1982). With regard to technological factors, the conditions of blanching and the length of the freezing and storage period must be taken into consideration (Lisiewska, 1986*a*; Lisiewska & Kmiecik, 1989).

*To whom correspondence should be addressed.

The aim of the present work was to determine the level of vitamin C in fresh broccoli and cauliflower as influenced by nitrogen fertilization, and to study the content of this vitamin as affected by the technological process of freezing and storing of the products at various temperatures.

## MATERIALS AND METHODS

### Materials

The broccoli cultivar, Corvet $F_1$, and cauliflower cultivar, Sernio RS, were grown in the autumn cycle in the experimental field of our department, located in southern Poland (Krakow region). The vegetables were grown in loamy–silty soil in the second year after farmyard manure fertilization (30 t $ha^{-1}$); 80 kg $P_2O_5$ $ha^{-1}$, 150 kg $K_2O$ $ha^{-1}$ and 40 kg N $ha^{-1}$ (in the form of ammonium nitrate) were applied prior to transplanting. The remaining part of the nitrogen fertilizer to give the experimentally required levels of 80 and 120 kg N $ha^{-1}$ was introduced as side dressing 3 and 5 weeks after planting, at doses of 40 kg N $ha^{-1}$. It should be stressed that the level of nitrogen fertilization was in accordance with Polish agrotechnical recommendations.

Harvesting was carried out in the second half of September. The broccoli and cauliflower were washed, divided into segments of about 5 × 5 cm, blanched in

water at 96–98°C for peroxidase inactivation (broccoli for 3 min, cauliflower for 4 min) at a water:vegetable ratio of 5:1, and dried in sieves. Samples were blast-frozen at an air velocity of 4 $ms^{-1}$ in a climatic Feutron 3101-01 chamber. The freezing of products down to storage temperatures of −20°C and −30°C lasted 30 and 50 min, respectively. The frozen products, packed in polythene bags, were stored for 12 months.

### Methods

Evaluation of the raw vegetables required measurement of the content of dry matter, ascorbic acid, total ascorbic and dehydroascorbic acids, and nitrates and nitrites. The successive stages of the investigation included the determination of dry matter and total ascorbic acid and dehydroascorbic acid levels in the blanched product and in frozen vegetables immediately after freezing and then after 3, 6, 9 and 12 months of storage.

The content of dry matter was determined using the gravimetric method (Association of Official Analytical Chemists, 1984). The contents of total ascorbic acid and dehydroascorbic acid were determined using 2,6-dichlorophenolindophenol–xylene extraction and a spectrophotometric method (ISO/6557/2). The contents of nitrates and nitrites were determined using a molecular absorption spectrometric method (ISO/6635).

All the analyses were carried out in four replications, each in two parallel samples. In statistical analysis the Snedecor *F*- and Student *t*-tests were applied at a probability error of $P = 0.05$.

## RESULTS AND DISCUSSION

The nitrogen fertilization doses of 80 and 120 kg N $ha^{-1}$ significantly increased the commercial yield of broccoli (80 kg $ha^{-1}$: 19.1 t $ha^{-1}$; 120 kg N $ha^{-1}$: 23.2 t $ha^{-1}$) and cauliflower (80 kg N $ha^{-1}$: 26.5 t $ha^{-1}$; 120 kg N $ha^{-1}$: 31.0 t $ha^{-1}$). With a dose of 120 kg N $ha^{-1}$, the heads produced were larger and their compactness met the requirements of the freezing industry for this type of raw material. With the higher dose of nitrogen the harvest was slightly delayed, although the delay did not exceed 3–5 days and was of no importance from the agrotechnical standpoint in the region of the experiment.

### Dry matter

Immediately after harvesting, the content of dry matter in broccoli and cauliflower was slightly smaller with the higher dose of nitrogen fertilizer, but no statistically significant differences were determined (Table 1). A similar tendency in dry matter content was recorded by Jha *et al.* (1973) and Nilsson (1980).

Blanching reduced the content of dry matter by 18–20% in broccoli and 9–10% in cauliflower, corresponding to a dry matter content of 9.1–9.5% in broccoli and 7.6–7.9% in cauliflower. Compared with cauliflower, broccoli lost distinctly more dry matter in the course of blanching, probably because of the different structure of this vegetable whose fairly loose heads could retain more water.

Probably on account of ice sublimation in the course of freezing and storing for 12 months, the content of dry matter increased by 1–4% compared to that found in the blanched material, to the level of 7.8–8.2% in cauliflower and 9.0–9.5% in broccoli. The increase in dry weight was smaller in frozen products stored at −30°C and in cauliflower was almost one-third that in broccoli, probably due to the greater compactness of cauliflower heads and hence reduced surface area.

### Nitrates

The content of nitrates in the fresh vegetables varied from 55.0 to 130.5 mg $N\text{-}NO_3$ $kg^{-1}$, exhibiting a characteristic medium ability to accumulate nitrates (Hansen, 1978). With an increase in the fertilization dose from 80 to 120 kg N $ha^{-1}$, the content of nitrates rose by 44% in broccoli and 33% in cauliflower (Table 1), confirming the role of nitrogen fertilization in the accumulation of these compounds (Greenwood & Hunt, 1986; Hansen, 1978).

In earlier studies (Lisiewska, 1986*b*; Lisiewska & Kmiecik, 1989; Lisiewska *et al.*, 1994), in general all the technological treatments in the process of vegetable freezing slightly reduced the content of nitrates and to a small extent increased the content of nitrites. Since the content of these compounds was small in the two species, no additional analyses were carried out at the different stages of freezing and storing.

**Table 1. Levels of selected physicochemical indices in fresh broccoli and cauliflower depending upon nitrogen fertilization**

| Vegetable | Fertilization (kg N $ha^{-1}$) | Dry matter[a] (%) | Fresh matter[a] | | |
|---|---|---|---|---|---|
| | | | Vitamin C (mg per 100 g) | $N\text{-}NO_3$ mg per 1000 g | $N\text{-}NO_2$ |
| Broccoli | 80 | 11.5 b | 116.4 c | 55.0 a | 0.15 a |
| | 120 | 11.4 b | 116.3 c | 79.4 b | 0.20 a |
| Cauliflower | 80 | 8.7 a | 64.7 b | 98.0 c | 0.28 b |
| | 120 | 8.4 a | 60.5 a | 130.5 d | 0.46 c |

[a]From four determinations.
[a,b,c]Values marked with the same letter do not differ significantly, LSD = 0.05.

## Vitamin C

The content of vitamin C in fresh broccoli was almost twice that in cauliflower (Table 1). A similar relationship was found by Albrecht *et al.* (1991). A statistically significant effect of nitrogen fertilization on the level of vitamin C was found in cauliflower, although the difference was only 6% in favour of the crop fertilized with a lower dose. Jha *et al.* (1973), Nilsson (1980) and Szwonek & Michalik (1991) reported that nitrogen fertilization did not affect the content of vitamin C in cauliflower. Maurya *et al.* (1992) showed that, with a higher dose of nitrogen, cauliflower contained significantly more vitamin C. The proportion of dehydroascorbic acid in total ascorbic acid was small in raw cauliflower and broccoli. Similar observations were made by Bushway *et al.* (1989).

The greater the initial content of vitamin C in raw vegetables, the greater were its losses during blanching. This tendency was observed in other vegetable species (Kmiecik & Lisiewska, 1989; Kmiecik *et al.*, 1990). Decreases in vitamin C content brought about by blanching were 41–42% in the case of broccoli and 28–32% in cauliflower. After blanching, the proportion of dehydroascorbic acid in vitamin C was 19–27% in broccoli and 2–3% in cauliflower. The freezing operation did not change the level of vitamin C, but the proportion of dehydroascorbic acid rose. Immediately after freezing the content of vitamin C was 67.2–68.6 mg per 100 g in broccoli and 44.0–45.2 mg per 100 g in cauliflower. In the two species this content was slightly greater in samples fertilized with the lower dose of nitrogen. Statistically significant differences in the levels of vitamin C were found only between the investigated samples of broccoli after 3 months of storage and of cauliflower after 3 and 6 months (Fig. 1). In cauliflower, this tendency was maintained during the entire storage period while no such dependence was found in broccoli. Losses in vitamin C content due to the 12-month storage period, compared to the content in the products directly after freezing, were 15–18% for broccoli and 6–13% for cauliflower. Within-species differences in the level of vitamin C after 12 months of storage were very small since broccoli contained 55–57 mg vitamin C per 100 g fresh weight and cauliflower 39–42 mg vitamin C per 100 g fresh weight.

The distributions of vitamin C losses in the different periods of determination, i.e. after 3, 6, 9 and 12 months, are shown in Figs 2 and 3, the losses due to the 12-month storage being taken as 100%. It was assessed that the losses of vitamin C were above all related to the species and the storage temperature. In the case of broccoli (Fig. 2), the storage temperature of −30°C permitted the retention of an unchanged level of vitamin C during 3 months and in the case of cauliflower (Fig. 3) during 6 months, while at −20°C the distribution of losses was more uniform during the entire storage period.

As related to the content determined in the product directly after freezing, the losses in vitamin C brought

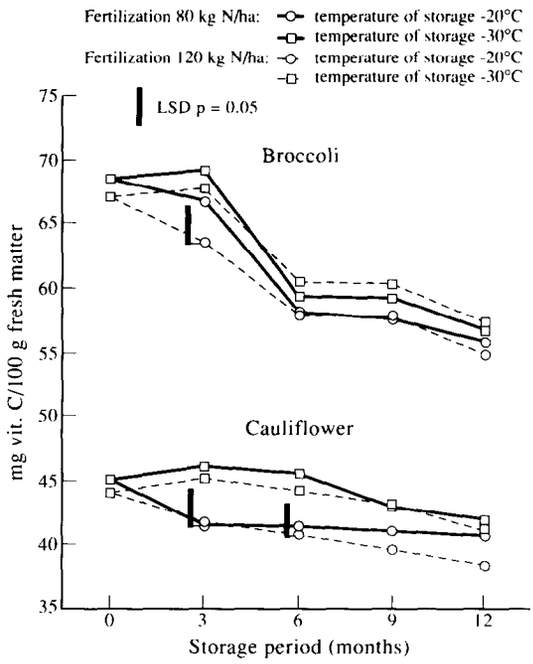


**Fig. 1.** Effect of storage on vitamin C levels in broccoli and cauliflower.

about by 12 months of storage amounted to 15–18% in broccoli and 6–13% in cauliflower. If the entire technological process of freezing and storage of frozen products is taken into consideration, i.e. the losses are related to the raw material, they amount to 51–53% and 32–37%, respectively. In the two species the losses were smaller with a storage temperature of −30°C, the maximum difference not exceeding 7%. During storage, the proportion of dehydroascorbic acid in vitamin C was 2–34%, being usually greater in samples stored at the higher temperature. The losses of vitamin C assessed

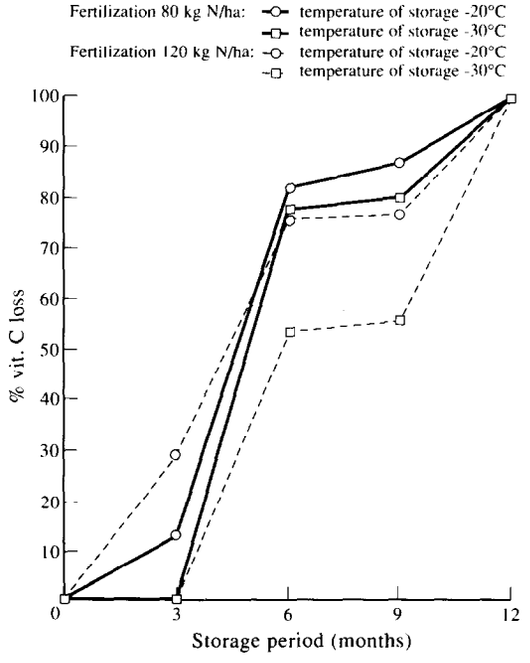


**Fig. 2.** Distribution of vitamin C losses in broccoli.

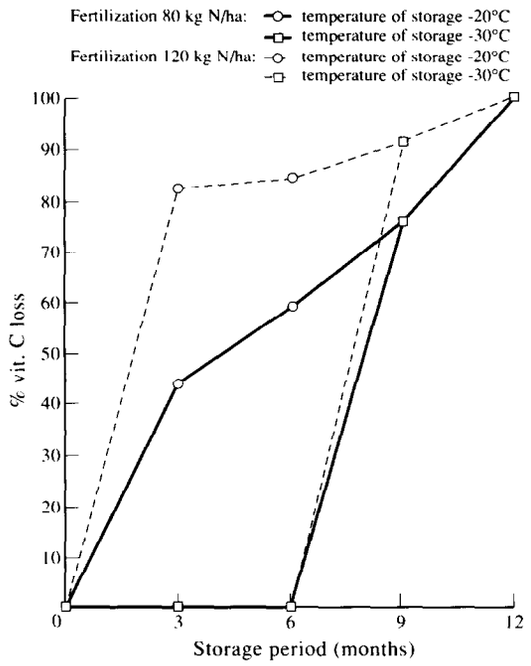


**Fig. 3.** Distribution of vitamin C losses in cauliflower.

in the work cannot be compared with other studies since different cultivars, temperatures and storage periods were used (Aparicio-Cuesta & Gracia-Moreno, 1988; Bąkowski *et al.*, 1990; Lisiewska, 1986*a*), but in general they were smaller than those reported in the cited literature.

## CONCLUSIONS

(1) Increasing the level of nitrogen fertilization from 80 to 120 kg N $ha^{-1}$ caused a decrease in vitamin C content in cauliflower, and an increased nitrate content of 44% in broccoli and 33% in cauliflower.

(2) During the freezing process, the greatest losses of vitamin C occurred from blanching: in broccoli 41–42%, in cauliflower 28–32%. The vitamin C content was reduced to 67.3–68.2 mg per 100 g fresh matter in broccoli and to 43.5–43.9 mg per 100 g of fresh matter in cauliflower.

(3) The freezing process itself did not bring about changes in the level of vitamin C, but during the 12 months of storage it decreased in broccoli (15–18%) to a greater extent than in cauliflower (6–13%). After 12 months, broccoli contained 54.9–57.4 mg of vitamin C per 100 g of the product and cauliflower 38.5–41.9 mg of vitamin C per 100 g.

(4) The level of nitrogen fertilization did not bring about losses of vitamin C in the processes of freezing and storing the vegetables.

(5) The storage temperature of the frozen product affected the losses of vitamin C to a certain extent. Smaller losses were recorded with the storage temperature of −30°C, mainly during the first 6 months of storage.

## REFERENCES

Albrecht, J. A., Schafer, H. W. & Zottola, E. A. (1991). Sulfhydryl and ascorbic acid relationships in selected vegetables and fruits. *J. Food Sci.*, **56**, 427–430.

Aparicio-Cuesta, M. P. & Gracia-Moreno, C. (1988). Quality of frozen cauliflower during storage. *J. Food Sci.*, **53**, 491–493.

Bąkowski, J., Kosson, R., Elkner, K. & Michalik, H. (1990). Wpływ techniki mrożenia kombinowanego na poprawe, jakości mrożonych kalafiorów. Cz. 2. *Chłodnictwo*, **11**, 13–16.

Block, G. & Langseth, L. (1994). Antioxidant vitamins and disease prevention. *Food Technol.*, **48**, 80–85.

Bushway, R. J., Helper, P. R., King, J., Perkins, B. & Krishnan, M. (1989). Comparison of ascorbic acid content of supermarket versus roadside stand produce. *J. Food Qual.*, **12**, 99–105.

Fitch, H. B. (1994). Antioxidants: health implications still debated. *Inform*, **5**, 242–252.

Greenwood, D. J. & Hunt, J. (1986). Effect of nitrogen fertilizer on the nitrate contents of field vegetables grown in Britain. *J. Sci. Food Agric.*, **37**, 373–383.

Hansen, H. (1978). The influence of nitrogen fertilization on the chemical composition of vegetables. *Qual. Plant. Plant Foods Hum. Nutr.*, **28**, 45–63.

Jha, J., Dwivedi, B. K. & Prasad, B. (1973). Effect of nitrogen fertilizer with and without organic manure on the quality of cauliflower. *J. Inst. Chem.*, **45**, 26–28.

Kmiecik, W. & Lisiewska, Z. (1989). Wpływ odmiany i wielkości główek na zawartość witaminy C w świeżej i mrożonej kapuście brukselskiej. *Roczn. PZH*, **40**, 215–222 (English summary).

Kmiecik, W. Lisiewska, Z. & Jaworska, G. (1990). Zawartość witaminy C w surowcu oraz w mrożonkach i konserwach apertyzowanych z bobu w zależności od odmiany i stopnia dojrzałogci nasion. *Roczn. PZH*, **41**, 17–24 (English summary).

Lisiewska, Z. (1986*a*). Wpływ temperatury i czasu składowania brokuła włoskiego na jakość surowca i wyprodukowanych z niego mrożkonek. *Biul. Warzywn.*, **30**, 213–230 (English summary).

Lisiewska, Z. (1986*b*). Zawartość azotanów i azotynów w świeżym i mrożonym brokule włoskim. *Bromat. Chem. Toksykol.*, **19**, 154–160 (English summary).

Lisiewska, Z. & Kmiecik, W. (1989). Zawartość azotanów w świeżej i mrożonej kapuście brukselskiej. *Bromat. Chem. Toksykol.*, **22**, 115–120 (English summary).

Lisiewska, Z., Kmiecik, W., Jaworska, G. & Gębczyński, P. (1994). Wpływ odmiany i stopnia dojrzałości nasion na zawartość azotanów i azotynów w świeżym i konserwowanym bobie. *Bromat. Chem. Toksykol.*, **27**, 17–22 (English summary).

Maurya, A. N., Chaurasia, S. N. S. & Reddy, Y. R. M. (1992). Effect of nitrogen and molybdenum levels on growth, yield and quality of cauliflower (*Brassica oleracea* var. Botrytis) cv. snowball-16. *Haryana J. Hortic. Sci.*, **21**, 232–235.

Nilsson, T. (1980). The influence of soil type, nitrogen and irrigation on yield, quality and chemical composition of cauliflower. *Swed. J. Agric. Res.*, **10**, 65–75.

Raber, F. & Kunsch, U. (1982). Uber den Einfluss des Erntezeitpunktes auf den Nitratgehalt von Karotten. *Ind. Obst. Gemueseverwert.*, **67**, 5–9.

Szwonek, E. & Michalik, H. (1991). Wpływ nawożenia azotowego na zawartość azotanów i witaminy C w kalafiorach. *Biul. Warzywn.*, **37**, 161–169 (English summary).

Tremblay, N. (1989). Effect of nitrogen sources and rates on yield and hollow stem development in broccoli. *Can. J. Plant Sci.*, **69**, 1049–1053.