ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. XIV SECTIO EEE 2004

Department of Vegetable and Medicinal Plants, Warsaw Agricultural University

MAREK GAJEWSKI

The Influence of Growing Period, Cultivar and Storage Conditions on Free Sterols Content in Cauliflower (*Brassica oleracea* L. var. *botrytis*)

Wpływ terminu uprawy, odmiany i warunków przechowywania na zawartość wolnych steroli w kalafiorze (*Brassica oleracea* L. var. *botrytis*)

Abstract. A study on free sterols concentration in four cauliflower cultivars – 'Panther', 'Isabel' F_1, 'Amfora' F_1 (cultivars with green curds) and 'Coleman' (cultivar with a white curd) – was carried out in 2001-2002. Cauliflowers were grown for harvest in spring, summer or autumn. The influence of gas composition of atmosphere during 6-weeks storage in a cold store (at the normal gas composition and at the CA 5% CO_2 + 3% O_2) on free sterols content in autumn cauliflowers was also examined. It was found that free sterols concentration was affected by a cultivar. Their concentration varied from 0.093 to 0.253 $mg \cdot g^{-1}$ of f.w. The highest concentration was shown by cv. 'Amfora' F_1 and the lowest – by cv. 'Coleman'. Free sterols content in cauliflowers grown in different periods was affected by climatic conditions before harvest and was the lowest for the spring period of growing in 2001 and for the summer period in 2002. During the storage of cauliflowers a declining sterols concentration was observed and CA conditions diminished these changes.

Key words – słowa kluczowe: CA – KA, cauliflower – kalafior, cultivars – odmiany, sterols – sterole, storage – przechowywanie

INTRODUCTION

Cultivars of cauliflower with green curds have been grown in Poland since the middle of the 1990's. These cultivars came from crossings made between white cauliflowers and broccoli (Crisp and Angell, 1985). Most cauliflowers are grown for the main crop in autumn and a short-term storage for this produce is often applied. Cauliflowers can be stored for a short period only, due to quality deterioration of the curds. According to Stoll (1974), Adamicki and Elkner

(1985) and Suslow and Cantwell (2002), optimum storage conditions for white cauliflower are: temperature of 0-1°C and 95-98% RH. Controlled atmosphere (CA) storage offers moderate benefit to white cauliflower cultivars, however 3-5% CO_2 + 2-3% O_2 was found as the best gas composition of atmosphere for white cauliflowers. Storage of cauliflowers for more than 3-4 weeks is not recommended. In order to keep good quality, wrapping curds with a stretch plastic film is applied (Ratti *et al.*, 1995). Adamicki and Elkner (1985) observed some flavour changes of cauliflowers, when CO_2 concentration in the atmosphere exceeded 5%. Green cultivars show a better storage ability than the white ones and they can be successfully stored at CA composition 5% CO_2 + 3% O_2, or 3% CO_2 + 3% O_2 (Gajewski, 1999; 2001). Green cultivars contain more dry matter and vitamin C than the white ones and show different sensory characteristics (Gajewski and Radzanowska, 2003).

Biological value of cauliflower results from the presence of different chemical compounds in the curds. It was found that plant sterols have antiflammary properties and beta-sitosterol works against prostate diseases. In a plant, they are essential structural and functional components of cell membranes (Piironen *et al.*, 2000). Total sterols content (i.e. free sterols plus sterols determined by acid and alkaline hydrolysis) in case of vegetables varies from 250 to 4100 $mg \cdot kg^{-1}$ of dry matter and for cauliflower the highest concentration of these compounds was found (Piironen *et al.*, 2003). According to USDA database (Anonymous, 2003), sterols content in fresh white cauliflower is equal to 18 $mg \cdot g^{-1}$ of f.w. Sitosterol is the predominant sterol (43-86% of total) for most vegetable species, including cauliflower (Normen *et al.*, 1999). No significant differences in sterols content between raw and cooked vegetables were found. However, Wang *et al.* (1992) observed a decline of free sterols concentration during storage of zucchini fruits and Krebsky *et al.* (1999) noticed an increase of free sterols in stored chicory heads (Belgian endive). Also an increase in stigmasterol to sitosterol ratio during the ageing of plant tissues was observed (Whitaker, 1995; Krebsky *et al.*, 1999).

The aim of this work was to determine free sterols content in different cultivars of cauliflower – green cultivars and the white one – and to examine the influence of growing period and storage conditions on the concentration of these compounds in curds.

MATERIAL AND METHODS

Plant material. Two-year experiments were carried out at the Department of Vegetable and Medicinal Plants of Warsaw Agricultural University in 2001-2002. Plants were grown from transplants in the experimental field in Warsaw-Wilanów on a silt soil, pH of about 7.0. Fertilizing was applied according to the results of soil analysis. Plants were chemically protected against pests and diseases, according to general recommendations. Climatic conditions during the growing season of

2001 and 2002 are shown in tab. 1. The data presented indicate that rainfalls in the seasons were very differentiated. The heaviest rainfalls took place in July 2001 and August 2002. The two seasons of experiment were quite warm and the temperature during all months was a little higher than the mean temperature for last 60 years.

Tab. 1. Mean temperature and rainfalls during growing seasons in 2001 and 2002

Month	Decade	Mean temperature (°C)		Rainfalls (mm)	
		2001	2002	2001	2002
May	1	18.1	18.9	1.8	0.0
	2	15.6	16.5	20.3	9.7
	3	13.6	18.0	17.6	68.5
June	1	14.5	16.4	3.8	28.3
	2	15.8	19.4	12.1	26.2
	3	17.8	18.7	17.8	4.3
July	1	20.5	21.3	36.2	34.9
	2	22.1	22.2	44.2	7.6
	3	21.5	20.8	68.2	0.1
August	1	19.8	21.3	17.6	64.8
	2	21.6	20.8	0.3	29.5
	3	18.8	20.7	17.2	0.8
September	1	14.7	19.1	17.2	0.0
	2	13.2	12.3	31.9	18.4
	3	10.0	10.1	24.1	12.2

Three green cultivars and one white cultivar were chosen. Cauliflowers were grown in three periods – spring, summer and autumn. They were sown, planted out and harvested at the terms shown below:

– spring period (I): sowing – 1st decade of March, planting out – 2nd decade of April, harvesting – 3rd decade of June;

– summer period (II): sowing – 3rd decade of April, planting out – 3rd decade of May, harvesting – 3rd decade of July;

– autumn period (III): sowing – 3rd decade of May, planting out – 3rd decade of June, harvesting – 3rd decade of September.

The harvest was performed at the optimum maturity stage of curds. Two experiments with cauliflowers were performed:

Experiment No. 1 The influence of growing period on free sterols content in different cauliflower cultivars. The two factors of this experiment were:

– Factor A: period of growing – spring (I), summer (II), autumn (III);

– Factor B: cultivar – 'Panther', 'Isabel' F_1, 'Amfora' F_1 (green cultivars), 'Coleman' (white cultivar).

The experiment was performed in four replications, with 30 plants taken for each replication.

Experiment No. 2 The influence of storage conditions (gas composition of atmosphere) on free sterols content in cauliflowers growed in autumn.

– Factor A: cultivar – as in the experiment No. 1 (see above);

– Factor B: storage condition – freshly harvested cauliflowers, cauliflowers stored at the normal atmosphere (NA), cauliflowers stored at the controlled atmosphere (CA 5% CO_2 + 3% O_2).

Curds were individually wrapped with a PE stretch film and the temperature of storage was equal to 0°C and RH equal to 95%. Cauliflowers were stored for 6 weeks. The experiment was performed in four replications and 8 curds of each replication were stored.

Samples of curds were taken for the analyses immediately after harvest and after storage from each replication. Free sterols content in cauliflowers in count on beta-sitosterol was determined by spectrophotometric method, according to Mrugasiewicz and Mścisz (1984). For the analysis of variance Anova program was applied and Tukey's HSD test was used to show which mean values for the studied factors of experiments differ significantly at P = 0.05.

RESULTS AND DISCUSSION

Free sterols (FS) content in freshly harvested cauliflowers varied from 0.093 to 0.253 mg · g^{-1} of f.w. (tab. 2). These values are similar to the values presented in Piironen *et al.* (2000) and Anonymous (2003) reports. FS level was significantly

Tab. 2. Free sterols content in cauliflower as affected by growing term and cultivar

Factors of experiment		Free sterols content (mg · g^{-1} f.w.)		
Growing period (A)	Cultivar (B)	2001	2002	Means of years
I (spring)	Amfora	0.163	0.243	0.203
	Isabel	0.145	0.253	0.199
	Panther	0.130	0.215	0.173
	Coleman	0.110	0.158	0.134
II (summer)	Amfora	0.250	0.178	0.214
	Isabel	0.200	0.145	0.173
	Panther	0.215	0.128	0.172
	Coleman	0.155	0.093	0.124
III (autumn)	Amfora	0.245	0.220	0.233
	Isabel	0.190	0.186	0.188
	Panther	0.225	0.198	0.212
	Coleman	0.160	0.153	0.157
Means for growing period	I	0.137 a	0.217 b	0.177 a
	II	0.205 b	0.136 a	0.171 a
	III	0.206 b	0.189 b	0.198 a
Means for cultivar	Amfora	0.219 c	0.214 b	0.217 b
	Isabel	0.178 b	0.195 b	0.187 b
	Panther	0.190 bc	0.180 b	0.185 b
	Coleman	0.142 a	0.135 a	0.139 a
LSD A x B (P = 0.05)		0.025	0.022	0.035

Note: Different letters in the same column indicate that means differ significantly according to Tukey's HSD test at P = 0.05. n.s. – interaction nonsignificant at P = 0.05

affected by cultivar in both years of the experiment. It was found that FS concentration in green cultivars was higher than in the white one. Differencesbetween green cultivars were significant only in the first year of the experiment. FS concentration for the three growing periods was different, but the differen-

tiation depended on the year of experiment – for 2001 the lowest concentration of FS was found in case of the first (spring) growing period, but for 2002 the lowest values were found for the second (summer) period. The reason for these phenomena may be related to climatic conditions, rainfalls especially. As it is shown in Tab. 1, the rainfalls at the time just before harvest were the lowest for the spring growing period in 2001 and for summer period in 2002. In both cases the cauliflowers showed the lowest FS concentration.

Tab. 3. Free sterols content in cauliflower as affected by cultivar and storage conditions

Factors of the experiment		Free sterols content (mg · g^{-1} f.w.)		
Cultivar (A)	Storage (B)	2001	2002	Means of years
Amfora	freshly harvested	0.245	0.220	0.233
	NA	0.160	0.102	0.131
	CA 5 + 3	0.195	0.175	0.185
Isabel	freshly harvested	0.190	0.186	0.188
	NA	0.115	0.127	0.121
	CA 5 + 3	0.145	0.165	0.155
Panther	freshly harvested	0.225	0.198	0.212
	NA	0.144	0.116	0.130
	CA 5 + 3	0.176	0.124	0.150
Coleman	freshly harvested	0.160	0.153	0.157
	NA	0.095	0.067	0.081
	CA 5 + 3	0.121	0.090	0.106
Means for cultivars	Amfora	0.200 c	0.166 b	0.183 b
	Isabel	0.150 ab	0.159 b	0.155 b
	Panther	0.182 bc	0.147 b	0.165 b
	Coleman	0.125 a	0.103 a	0.114 a
Means for storage	freshly harvested	0.205 b	0.189 c	0.197 c
	NA	0.129 a	0.103 a	0.116 a
	CA 5 + 3	0.159 b	0.139 b	0.149 b
LSD A x B (P = 0.05)		0.025	0.020	0.025

Note: see Tab. 3
NA – normal atmosphere; CA 5 + 3 – controlled atmosphere 5% CO_2 + 3% O_2

A significant influence of storage at different gas composition on FS content in cauliflowers was observed in both years of the experiment (tab. 3). Freshly harvested curds showed higher concentration of FS than the stored ones, but storage at CA conditions inhibited changes in FS concentration compared with storage at the normal atmosphere. The influence of cultivar on FS concentration in stored cauliflowers was also significant. Green cauliflowers showed higher FS concentration than white cauliflowers after storage. In the author's other experiments it was observed that green cultivars of cauliflower, cv. 'Amfora' F_1 especially, show a better storage ability than the other cultivars (Gajewski, 1999; 2001).

CONCLUSIONS

1. Free sterols concentration in freshly harvested cauliflower curds is affected by cultivar and climatic conditions during the vegetation season. Green cauliflower cultivars ('Amfora' F_1, 'Isabel' F_1, 'Panther') show a higher sterols concentration than the white one (cv. 'Coleman'). Sterols concentration remains higher for green cultivars also after storage.

2. During the storage of cauliflowers a decline of free sterols concentration occurs, however, CA storage conditions inhibit these changes as compared with the normal atmosphere storage.

REFERENCES

Adamicki F., Elkner K., 1985. Wpływ temperatury i kontrolowanej atmosfery na przechowywanie i jakość kalafiorów. (The influence of temperature and controlled atmosphere on storage and quality of cauliflower). Biul. Warzywn., XXVIII: 197-223. [In Polish]

Anonymous, 2003. Cauliflower Raw. USDA National Nutrient Database for Standard Reference, Release 16: 11135.

Crisp P., Angell S.M., 1985. Genetic control of green curd colour in cauliflower. Ann. Appl. Biol., 107: 601-603.

Gajewski M., 1999. Ocena jakości i zdolności przechowalniczej odmian kalafiorów zielonych różach. (Quality and storage ability of green cauliflower cultivars). Zesz. Probl. Post. Nauk Roln., 466: 219-225. [In Polish, with English summary]

Gajewski M., 2001. Wpływ kontrolowanej atmosfery na jakość kalafiorów o zielonych różach. (The influence of CA on green cauliflower quality). Folia Hortic., 13/1A: 267-272. [In Polish, with English summary]

Gajewski M., Radzanowska J., 2003. The effect of storage on sensory quality of green cauliflower cultivars (*Brassica oleracea* L. var. *botrytis*). Veget. Crops Res. Bull., 59, in press.

Krebsky E., Geuns J.M.C., De Proft M., 1999. Polyamines and sterols in *Cichorium* heads. Phytochem., 50: 549-553.

Mrugasiewicz K., Mścisz A., 1984. Metoda oznaczania steroidów w kukurydzy (*Zea mays* L.). (Methods of sterols determination in corn (*Zea mays* L.)). Herba Polon., 30(2): 97-100. [In Polish]

Piironen V., Toivo J., Puupponen-Pimia R., Lampi A.M., 2003. Plant sterols in vegetables, fruits and berries. J. Sci. Food Agric., 83: 330-337.

Piironen V., Lindsay D.G., Miettinen T.A., Toivo J., Lampi A.M., 2000. Plant sterols: biosynthesis, biological function and their importance to human nutrition. J. Sci. Food Agric., 80: 939-966.

Ratti C., Raghavan G.S.V., Gariepy Y., 1996. Respiration rate model and modified atmosphere packaging of fresh cauliflower. J. Food Eng., 28: 297-306.

Stoll K. 1974. Storage of vegetables in modified atmospheres (CA). Acta Hortic., 38: 13-22.

Suslow T.V., Cantwell M., 2002. Cauliflower. Produce facts. UC Davis. http://rics.ucdavis.edu.

Wang C., Kramer G., Whitaker B., Lusby W., 1992. Temperature preconditioning increases tolerance to chilling injury and alters lipid composition in zucchini squash. J. Plant Physiol., 140: 229-235.

Whitaker B. D., 1995. Lipid changes in mature-green bell pepper fruit during chilling at 2°C and after transfer to 20°C subsequent to chilling. Phys. Plant., 93: 683-688.

STRESZCZENIE

W latach 2001-2002 badano zawartość wolnych steroli w różach czterech odmian kalafiora – 'Panther', 'Isabel' F_1, 'Amfora' F_1 (o zielonych różach) oraz 'Coleman' (o białej róży) zależnie od terminu uprawy – termin wiosenny, letni i jesienny. Badano również zmiany w zawartości wolnych steroli w kalafiorach z jesiennego terminu uprawy w wyniku przechowywania przez 6 tygodni w chłodni w dwóch składach gazowych atmosfery – normalnym i w KA o składzie 5% CO_2 + 3% O_2. Rezultaty doświadczeń wykazały, że zawartość steroli zależy od odmiany. Odmiany o zielonych różach zawierały więcej steroli niż odmiana biała. Wpływ terminu uprawy był zróżnicowany w zależności od roku – w pierwszym roku doświadczenia najniższą zawartość steroli stwierdzono u kalafiorów z wiosennego terminu uprawy, a w drugim – z letniego terminu uprawy. W czasie przechowywania stwierdzono zmniejszanie się koncentracji steroli, jednak w chłodni KA zmiany te były mniejsze niż w chłodni z normalną atmosferą.