Effects of fertilization and environmental conditions on anthocyanin content of red cabbage

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Introduction

Anthocyanins are water soluble pigments widely used in the food industry to color soft drinks, jams, and dairy products and are classified as E-163 by the European Community and as 21 CFR 73 by the American Food and Drug Administration. They are also known for their benefits to human health showing antioxidant activity (Tamura and Yamagami, 1994), anticancer properties (Kamei et al., 1995), visual acuity promotion (Muth, 2000), and a probable defense effect against coronary heart disease (Bettini, 1985).Up to now these pigments are mainly extracted from the pomace of grape but some problems related to vineyard cultivation, stress the need of more versatile crops as sources of natural red colorants. Moreover red cabbage has a complex pattern of acylated anthocyanins with cyanidin as the only aglycone (Shimizu et al., 1997). The acylation plays an important role in maintaining color in food systems because it improves both heat and light stability (Malien-Aubert et al., 1982).

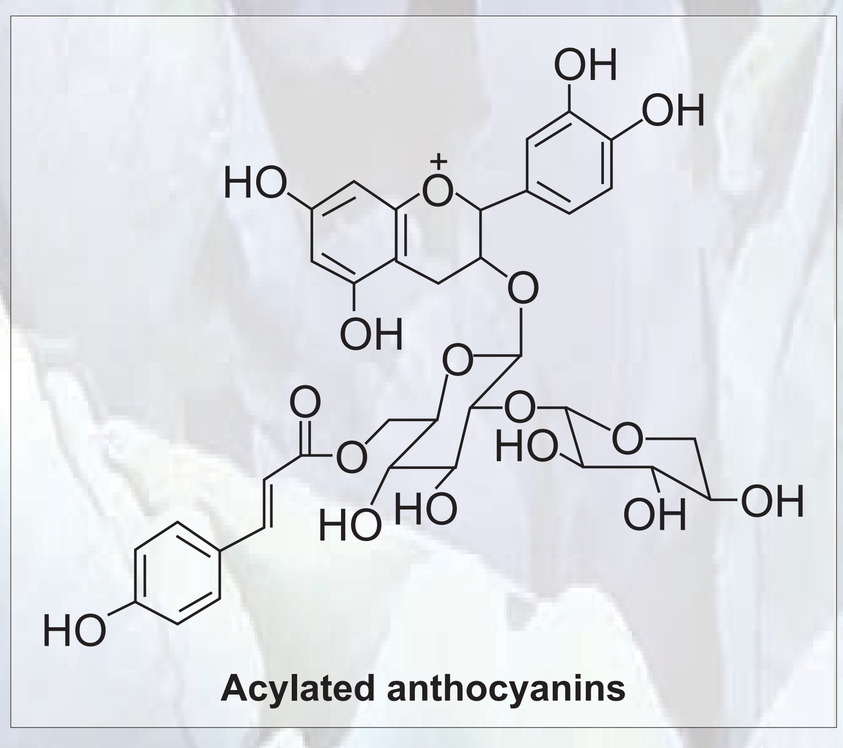
Materials and methods

Plant material.

Two hybrids ('Roxy' and 'Gradur') were grown in North and Central Italy at the experimental farm of Bologna University, in Ozzano dell'Emilia (Bologna) and in a private farm, under a factorial combination of increasing rates of potassium sulphate (0–50–100 kg K ha^{-1}) and superphosphate (0–39–78 kg P ha^{-1}) applied before planting. Cabbages were transplanted at the beginning of August and harvested in winter.

Anthocyanin extraction,analysis and quantification.

- Fresh material (5 g) was homogenized with 50 mL of HCl in methanol 1% v/v solution and kept for 12 h at 4°C in dark. After filtration, the residue was washed twice with 25 mL of the same solution and diluted in water to obtain a final volume of 100 mL.
- The analyses were performed by spectrophotometry reading the extract absorbance at 530 nm.
- The anthocyanins were expressed as cyanidin-3-glucoside, considering that all cabbage anthocyanins derive from cyanidin glucoside whose molar extinction in 1% HCl in methanol is 34.300.



Acylated anthocyanins

Results and discussion

Cabbage yields were always higher in Falconara than in Ozzano (**Table 1**).
The yields of the two hybrids were quite similar: only in 1997 in Falconara 'Roxy' produced 33% more than 'Gradur'.

Anthocyanin content in cabbage head (**Table 2**) was 12.4 g kg^{-1} DM, on average, and varied between 10 ('Roxy in Falconara, 1996) and 19 g kg^{-1} (Gradur in Falconara, 1997).

The difference between cultivars was wide and stable: on average, 'Roxy' showed a 30% lower content than 'Gradur'. On the whole, the resulting pigment yield was high, particularly in Central Italy (**Table 3**). The 98 kg ha^{-1} of extractable anthocyanins reached with 'Gradur' in Falconara in 1996, shows the high yield potential of this crop. In this environment satisfactory pigment yields were also obtained in the less favorable 1997 (66 kg ha^{-1}, on average). In Ozzano pigment yields were always lower: in the favourable 1997 they were almost half of what obtained in Falconara. In the first year Ozzano yields were reduced by a heavy infection of soft rot disease probably favored by the previous potato crop.

The importance of a well balanced fertilization was evident only regarding anthocyanin content in the heads (**Table 4**). The other crop parameters were only slightly influenced. On the whole, the highest pigment concentration was obtained with the highest potassium rate (100 kg K ha^{-1}) at the medium phosphorous level (39 kg P ha^{-1}). As expected, a common pattern was the depression of anthocyanin content at the highest application rates of both fertilizers (78 kg P ha^{-1} and 100 kg K ha^{-1}).

Table 1. Cabbage yield (t ha^{-1} of fresh heads). Averages of 9 fertilization treatments.

	Year 1996		Year 1997	
	Falconara	Ozzano	Falconara	Ozzano
Roxy	70.1	17.5	43.8	29.1
Gradur	73.6	17.3	32.9	27.0
Mean	71.8	17.4	38.3	28.0
ANOVA F with 1-6 d.f.	13 *	0.02 NS	119 ***	5 NS

*, **, *** = Differences between means significant at P≤ 0.05, 0.01, 0.001, respectively, NS

Table 2. Anthocyanin content in cabbage head (g kg^{-1} DM). Averages of 9 fertilization treatments.

	Year 1996		Year 1997	
	Falconara	Ozzano	Falconara	Ozzano
Roxy	10.0	10.6	15.4	10.6
Gradur	14.0	12.1	19.1	12.4
Mean	12.0	11.4	17.3	11.5
ANOVA F with 1-6 d.f.	40 ***	6 NS	34 **	8 *

*, **, *** = Differences between means significant at P≤ 0.05, 0.01, 0.001, respectively, NS

Table 3. Anthocyanin yield (kg ha^{-1} of extractable pigment). Averages of 9 fertilization treatments.

	Year 1996		Year 1997	
	Falconara	Ozzano	Falconara	Ozzano
Roxy	66.5	17.5	62.9	31.2
Gradur	98.0	19.7	69.7	36.2
Mean	82.3	18.6	66.3	33.7
ANOVA F with 1-6 d.f.	99 ***	0.3 NS	5 NS	2 NS

*, **, *** = Differences between means significant at P≤ 0.05, 0.01, 0.001, respectively, NS =

Table 4. Interaction between K and P fertilization on anthocyanin content in cabbage heads (g kg^{-1} DM). Averages of the two hybrids. Linear components were never significant.

P (kg ha^{-1})	K (kg ha^{-1})	Falconara (1996)	Falconara (1997)	Ozzano (1996)	Ozzano (1997)
0	0	12.3	16.9	11.1	11.1
	50	12.7	17.0	11.2	11.4
	100	12.3	16.5	11.3	11.5
39	0	11.3	17.5	11.3	11.0
	50	12.7	17.9	11.6	12.0
	100	12.4	17.9	11.5	12.0
78	0	11.6	17.4	11.6	11.5
	50	12.2	17.2	12.2	12.0
	100	10.6	17.0	10.6	11.2
Significance	*	NS	NS	*	NS
LSD P≤0.05		1.1		1.2	

* = Differences between means significant at P≤ 0.05; NS = significance P>0.05

Conclusions

Red cabbage contained many anthocyanins with favorable stability characteristics due to a strong acylation.

The varietal choice appeared the most important factor of success in pigment yield.

Fertilization had only a slight effect.

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