Nutrients content and yield in selected cultivars of leaf lettuce *(Lactuca sativa* L. var. *crispa)*

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ABSTRACT: Five cultivars of leaf lettuce (Lactuca sativa L. var. crispa) – Bergamo, Dubáček, Frisby, Lollo Rossa and Redin – were evaluated in two-year experiments carried out at the Faculty of Horticulture in Lednice (Mendel University of Agriculture and Forestry in Brno). Experiments were conducted in two trial years, 1998 and 1999; the lettuce was cultivated in three seasons: spring, summer and autumn. After the harvest, contents of following nutrients were evaluated: vitamin C, minerals (K, Na, Ca, Mg), fibre, dry matter and nitrates. The weight of leaf rosette was also recorded. The contents of selected substances and weights of leaf rosette were ranged as follows: vitamin C (65 to 302 mg/kg), potassium (2,394 to 6,477 mg/kg), sodium (39 to 223 mg/kg), calcium (200 to 755 mg/kg), magnesium (110 to 413 mg/kg), fibre (4.98 to 12.22 g/kg), dry matter (59 to 140 g/kg), nitrates (293 to 3,817 mg/kg) and the weight of leaf rosette (164 to 502 g). A significant influence of cultivar was found in the case of K, Na, and Ca content, as well as in dry matter and weight of leaf rosette. The growing season affected significantly all the evaluated substances, except for fibre. The year of cultivation affected all the evaluated parameters but Ca. It appears from the results that the contents of monitored substances were significantly influenced by cultivar as well as by growing season and year.

Keywords: leaf lettuce (*Lactuca sativa* L. var. *crispa*); cultivars; nutrients

The consumption of vegetables in the EU countries has already exceeded 130 kg per person a year. In the Czech Republic the consumption has increased from 66 kg in the 1990s to 80 kg at present. It can be presumed that the consumption of vegetable in the Czech Republic will gradually increase and will approach the values reported in the rest of the EU. The requirements of consumers also increase and the producers try to meet them. A significant influence of vegetables on human health is being emphasized and the demand for leaf vegetables rises; it concerns mainly head, ice-berg and leaf lettuce and Chinese cabbage but also some other, less available species.

The leaf lettuce has been gaining more and more popularity among consumers and occupies a stable position in the assortment of leaf vegetables. This lettuce does not form any solid heads but only a group of leaves of various shapes and colours (red, reddish, green, yellow). Owing to this composition, leaf types of lettuce should contain more fibre, minerals and vitamins than head lettuce (Ryder 1999). The content of nutrients is dependent on growing conditions, namely: temperature (Karmas, Harris 1988), nutrition and means of fertilization (Ducsay, Varga 2003; Premuzic et al. 2004), irrigation (Panchal et al. 2001; Radovich et al. 2005), cultivation methods (Worthington 2001) and, last but not least, cultivar (Petříková, Pokluda 2003; Ghebramlak et al. 2004).

MATERIAL AND METHODS

Characteristics of cultivars

Bergamo – type of Lollo Bionda lettuce**,** fresh green colour of strongly crimped leaves, leaf rosette has globular shape (Anonymous 2000).

Dubáček – cultivar registered in 1986 **(**Moravoseed, s. r. o., Mikulov – Mušlov); lettuce for cutting of oak-leaf type, with light green, strongly lobed leaves, highly resistant to bolting, suitable for spring, summer and autumn outside growing (Anonymous 1999).

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Frisby – cultivar recorded in 1996; leaf lettuce suitable for outside growing. Leaves are green, slightly serrated with fine nerves. Cultivar is resistant to bolting (Keller et al. 1996).

Lollo Rossa – attractive red-brown lettuce of Lollo Rossa type. Strongly crimped leaves make compact rosette. Suitable for spring, summer and autumn crop (Anonymous 1998).

Redin – cultivar registered in 1996 (Moravoseed, s. r. o., Mikulov – Mušlov); lettuce with red, intensively lobed leaves (oak-leaf type) and good resistance to bolting, suitable for spring, summer and autumn outside cultivation (Anonymous 1999).

Terms of leaf lettuce growing

Spring term – sowing: mid February, outplanting: end of March, harvest: early May.

Summer term – sowing: end of April, outplanting: early June, harvest: mid August.

Autumn term – sowing: early July, outplanting: mid August, harvest: end of September.

Field experiments were carried out in the years 1998 and 1999. The lettuce was cultivated on the field in Lednice (Mendel University of Agriculture and Forestry in Brno) situated 164 m above sea level. Lednice lies in the southeastern part of the Czech Republic with a warm and dry climate and light soil. Its average annual precipitation is 524 mm, precipitation during the vegetation period is 323 mm and average annual temperature is 9°C.

The experiments were set in a randomized block design with three replications and plots of 12 m^2. Lettuce was cultivated according to the recommended technology (Malý et al. 1996). Standard fertilization (on the basis of soil sample tests results), irrigation and weed control practices were used. The transplants were planted in the following spacing: 0.25 × 0.30 m (Dubáček, Redin) and 0.20 × 0.25 m (Bergamo, Frisby, Lollo Rossa). The lettuce was harvested in a phase corresponding to ČSN 46 3132 standard (for lettuce) – minimal weight of leaf rosette 150 g.

The analyses of nutrients contents were performed after harvest. A mixed sample was done from three plants of each repetition.

Methods of determining contents

Vitamin C (L. – ascorbic acid) – determined by the Tillmans titration method.

Minerals (K, Na, Ca, Mg) – determined by means of the capillary isotachophoresis method on IONOSEP 900.1.

Fibre – a method according to Henneberg-Stohmann.

Dry matter – direct sample dried at 103 ± 2°C.

Nitrates – Ion selective electrode by Šenkýř (ISE).

The results of nutrients content and weight of leaf rosette were statistically evaluated by an analysis

Table 1. Nutrients content in fresh matter and weight of leaf lettuce rosette (1998)

Cultivar	Vitamin C	Potassium	Sodium	Calcium	Magnesium	Fibre	Dry matter	Nitrates (mg/kg)	Weight of leaf rosette (g)	Cultivation time
			(mg/kg)			(g/kg)				
Lollo Rossa	–	3,746	70	**363**	146	**6.74**	70	**3,817**	198	
Redin	–	**4,165**	**76**	319	152	6.56	**79**	2,717	**347**	
Bergamo	242	2,971	56	293	119	6.63	71	3,250	288	spring 1998
Dubáček	255	3,094	49	238	122	5.54	71	2,983	271	
Frisby	**278**	3,251	66	239	**156**	5.56	70	3,300	234	
Lollo Rossa	–	**3,388**	**107**	**449**	132	10.71	100	1,193	336	
Redin	–	2,895	46	423	**138**	6.19	59	1,423	424	
Bergamo	111	2,600	59	273	112	**12.22**	**118**	887	387	summer 1998
Dubáček	130	2,770	39	306	115	7.58	81	**1,807**	**428**	
Frisby	**151**	2,758	63	325	114	11.02	104	1,043	351	
Lollo Rossa	–	2,517	48	440	131	**7.13**	**74**	1,883	216	
Redin	–	**3,711**	49	410	122	5.64	68	1,643	**328**	
Bergamo	**117**	3,272	**65**	**483**	138	6.66	67	1,883	297	autumn 1998
Dubáček	116	3,062	46	261	120	6.12	73	**2,327**	302	
Frisby	65	3,579	51	475	**235**	5.17	60	2,200	326	

– not set

Table 2. Nutrients content in fresh matter and weight of leaf lettuce rosette (1999)

Cultivar	Vitamin C	Potassium	Sodium	Calcium	Magnesium	Fibre	Dry matter	Nitrates (mg/kg)	Weight of leaf rosette (g)	Cultivation time
			(mg/kg)			(g/kg)				
Lollo Rossa	–	3,725	**84**	250	**176**	**10.94**	**118**	607	234	
Redin	–	**5,035**	54	247	110	6.11	73	**1,423**	423	
Bergamo	**222**	3,554	53	**274**	114	7.62	89	867	213	spring 1999
Dubáček	216	3,791	47	204	116	4.98	62	1,330	**466**	
Frisby	174	3,691	57	250	171	6.70	74	1,333	246	
Lollo Rossa	–	3,343	**107**	**425**	126	**9.39**	**96**	570	277	
Redin	–	**3,594**	68	337	184	7.65	73	293	**502**	
Bergamo	138	2,495	80	238	154	8.89	80	385	283	summer 1999
Dubáček	110	2,394	49	200	120	7.24	73	480	459	
Frisby	**182**	3,370	73	358	**226**	7.73	84	**610**	297	
Lollo Rossa	–	**6,477**	**223**	419	345	**9.38**	**140**	1,083	164	
Redin	–	6,088	106	522	380	7.48	125	1,110	245	
Bergamo	179	5,205	107	662	380	8.05	120	1,043	187	autumn 1999
Dubáček	199	5,974	138	**755**	**413**	8.98	131	**1,423**	**284**	
Frisby	**302**	5,751	141	506	371	8.73	128	1,133	175	

– not set

of variance with determining significance at level $P = 0.05$ and $P = 0.01$, using the statistical program Unistat (version 5.1).

RESULTS AND DISCUSSION

Differences of nutrients content and weights of leaf rosette in relation to year, term of cultivation and cultivar

Vitamin C

Comparing the three vegetation terms in 1998 the highest content of vitamin C (278 mg/kg) was found for cv. Frisby cultivated in the spring time (Table 1). In 1999 the highest content of vitamin C (302 mg per kg) was also reported for cv. Frisby but cultivated in the autumn time (Table 2). The differences among cultivars were not statistically significant (Table 3). Significant differences in vitamin C content among lettuce cultivars were found by Petříková and Pokluda (2003) and among Chinese cabbage cultivars by Malý (2003). In 1998, the contents of vitamin C were statistically higher for lettuce cultivated in spring than in autumn and summer; the lowest level of vitamin C was reported for lettuce cultivated in autumn.

In 1999, the levels of vitamin C were statistically higher for lettuce from the autumn and spring vegetation period compared to the summer period (Table 4). There are significant differences in vitamin C contents between 1998 and 1999 for lettuce cultivated in the autumn time (Table 5). The content of vitamin C is significantly influenced by various vegetation factors and by the time and year; it is impossible to decide which period is the most suitable for lettuce cultivation with respect to the content of vitamin C, since the conditions in individual vegetation periods differed. Temperature, humidity, sunshine and other conditions in the vegetation period play an important role in vitamin C production. A significant influence of weather condition and geographical latitude on vitamin C contents is documented by Hardh (1971) in Hägg et al. (1994). The authors listed significant differences of vitamin C contents in particular years of cultivation depending on the weather conditions and other vegetation factors. The authors reported also the influence of latitude on the content of vitamin C in lettuce; the lettuce cultivated in northern areas exhibited several times lower levels of vitamin C than lettuce cultivated in southern areas.

Minerals (K, Na, Ca, Mg)

Content of minerals in leaf lettuce ranged as follows: potassium (2,394–6,477 mg/kg), sodium (39 to 223 mg/kg), calcium (200–755 mg/kg), magnesium (110–413 mg/kg) (Tables 1 and 2).

Table 3. Effect of cultivar on statistical differences in nutrients content and the weight of leaf lettuce rosette

	Bergamo												Dubáček												Frisby												Lollo Rossa											
	Vitamin C	Fibre	Dry matter	Nitrates	Potassium	Sodium	Magnesium	Calcium	Weight of leaf rose	Vitamin C	Fibre	Dry matter	Nitrates	Potassium	Sodium	Magnesium	Calcium	Weight of leaf rose	Vitamin C	Fibre	Dry matter	Nitrates	Potassium	Sodium	Magnesium	Calcium	Weight of leaf rose	Vitamin C	Fibre	Dry matter	Nitrates	Potassium	Sodium	Magnesium	Calcium	Weight of leaf rose	Vitamin C	Fibre	Dry matter	Nitrates	Potassium	Sodium	Magnesium	Calcium	Weight of leaf rose
Redin			++		++			++	++					++	++		++	++			++																									
Lollo Rossa					++	++		++	++			+		++	++		++							++		+	+																			
Frisby					++			+	++						++		+																															
Dubáček			+			++			++																																							

+ significant difference $P = 0.05$, ++ significant difference $P = 0.01$
The values used for statistical analysis are means from 6 cultivation periods (spring 1998, summer 1998, autumn 1998, spring 1999, summer 1999, autumn 1999)

Potassium

In 1998 the highest level of potassium was found in Redin cultivated in the spring time – 4,165 mg/kg (Table 1); in 1999 it was cv. Lollo Rossa cultivated in the autumn time 6,477 mg/kg (Table 2).

The content of K in leaf lettuce recorded in this study is higher than in the experiments of Rubatzky and Yamaguchi (1997) cited by Ryder (1999).

In both years, the levels of K were statistically higher for lettuce cultivated in spring and autumn compared to the summer time (Table 4). In 1998 the content of K was significantly higher in red Redin cultivar than in Bergamo and Dubáček cultivars.

The influence of year on K content was found for lettuce cultivated in the spring time (Table 5). Statistically higher content of K was found in cv. Redin than in cultivars Dubáček, Bergamo, Frisby, Lollo Rossa, and similarly for Lollo Rossa cultivar in comparison with Dubáček cultivar (Table 3). In the summer term, the content of K was statistically higher in Lollo Rossa, Redin and Frisby cultivars than Bergamo cultivar, and in Lollo Rossa, Redin and Frisby in comparison with Bergamo and Dubáček cultivars (Table 3). In autumn cultivation time, the influence of year on K content was considerable as well (Table 5). The higher content of K for lettuce cultivated in the autumn time compared to the summer cultivation was found by Petříková et al. (2004).

Sodium

Sodium is usually in surplus in human nourishment. Its low content in vegetables is therefore viewed as positive. The Na content was in the range from 39 to 223 mg/kg (Tables 1 and 2); majority of values was lower than the level of 90 mg/kg, which is listed by Rubatzky and Yamaguchi (1997) and cited by Ryder (1999). The amount of sodium in leaf lettuce was influenced by cultivar (Table 3), growing term (Table 4) and year (Table 5). The lowest sodium content was found in Dubáček (Table 1).

Calcium

In 1998 the highest content of Ca was found in cv. Bergamo cultivated in the autumn term – 483 mg/kg (Table 1); in 1999 Dubáček cultivated in autumn reached even 755 mg/kg (Table 2).

The results of this study show that the content of Ca ranges from 121 to 755 mg/kg (Tables 1 and 2). The values were usually lower than 680 mg/kg listed by Rubatzky and Yamaguchi (1997) and cited by Ryder (1999). The content of calcium was influenced

Table 4. The influence of cultivation time on statistical differences in nutrients content in leaf lettuce (1998–1999)

	Spring									Summer								
	Vitamin C	Potassium	Sodium	Calcium	Magnesium	Fibre	Dry matter	Nitrates	Weight of leaf rose	Vitamin C	Potassium	Sodium	Calcium	Magnesium	Fibre	Dry matter	Nitrates	Weight of leaf rose
Autumn	++	++	+	++	++					++	++		++	++		+	+	++
Summer	++	++						++	++									

+ significant difference $P = 0.05$, ++ significant difference $P = 0.01$
The values used for statistical analysis are means from two years (1998 and 1999)

by cultivar (Table 3), cultivation time (Table 4) but not by year (Table 5).

Significantly higher content of Ca in head lettuce cultivated in the autumn time compared to the summer time was shown by Petříková et al. (2004).

Magnesium

In 1998 the highest content of Mg was found in cv. Frisby cultivated in the autumn time – 235 mg/kg (Table 1); in 1999 it was in Dubáček cultivated also in the autumn time – 413 mg/kg (Table 2).

The levels of Mg content ranged from 91 to 413 mg/kg (Tables 1 and 2), it is similar to the results previously reported by Kopec (1998) in head lettuce. The amount of magnesium was influenced by cultivar (Table 3), cultivation time (Table 4) and year of investigation (Table 5).

Fibre

In 1998 the highest content of fibre was found in Bergamo cultivated in the summer time – 12.22 g/kg (Table 1), and in 1999 in Lollo Rossa cultivated in the spring time – 10.94 g/kg (Table 2).

Neither the cultivation time (Table 4) nor the cultivar (Table 3) influenced the content of fibre.

The levels of fibre content in cv. Lollo Rossa cultivated in spring were statistically higher in comparison with Dubáček cultivar (Table 3). The influence of year on the fibre content was observed for lettuce cultivated in the autumn time (Table 5).

The content of fibre (7 g/kg), reported by Rubatzky and Yamaguchi (1997) and cited by Ryder (1999) is similar to the results of our experiments (4.98 g/kg to 12.22 g/kg) (Tables 1 and 2). The higher level of fibre content was noted in 1999 in comparison with 1998 (Table 5), which is related to different weather conditions in the trial years as well as to some other vegetation factors.

Dry matter

In 1999, the levels of dry matter were statistically higher for lettuce cultivated in the autumn time in comparison with lettuce from the summer time (Table 4).

The levels of dry matter content were statistically higher in cvs. Bergamo, Lollo Rossa and Frisby cultivated in summer than in Redin, and there were statistically higher levels of dry matter content in cv. Bergamo and Lollo Rossa cultivars compared to Dubáček cultivar (Table 3). Statistically significant differences of dry matter content were found between summer and autumn growing terms (Table 4). The quantity of light energy is listed by Reinink (1993) as a significant factor influencing dry matter content in lettuce. In periods with higher intensity of light a tendency to accumulate a greater

Table 5. Statistical differences in nutrients content between two trial years: 1998 and 1999

	Vitamin C	Potassium	Sodium	Calcium	Magnesium	Fibre	Dry matter	Nitrates	Weight of leaf rose
	1998								
1999	++	+	+		++	++	++	++	++

+ significant difference $P = 0.05$, ++ significant difference $P = 0.01$
The values used for statistical analysis are means from three periods (spring, summer and autumn)

Table 6. Meteorological characteristics of Lednice area in 1998 and 1999

Month		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	IV.–IX.	I.–XII.
Air temperature (°C)	1998	1.6	4.2	4.7	12.3	15.7	19.5	20.4	20.1	14.7	10.2	1.6	–1.4	17.1	10.3
	1999	–1.3	0.4	4.7	9.5	14.8	17.7	19.5	19.0	14.6	9.2	3.9	0.2	15.9	9.3
Precipitation (mm)	1998	13.0	1.9	15.9	39.2	25.8	101.1	57.0	42.4	112.0	90.2	20.1	7.4	377.5	526.0
	1999	9.1	14.1	2.1	32.7	37.7	98.0	108.2	31.6	36.2	13.0	46.1	32.7	344.4	486.5
Irradiance period (h)	1998	54	105	146	170	248	235	217	257	123	82	71	36	1,255	1,748
	1999	31	52	135	192	224	203	260	222	191	126	41	54	1,293	1,731

amount of dry matter was observed. Leclerc et al. (1996) showed a negative correlation between dry matter content and the weight of lettuce.

Nitrates

In 1998 the highest content of nitrates was found in cv. Lollo Rossa cultivated in the spring time – 3,817 mg/kg (Table 1), and in 1999 in Dubáček cultivated in the autumn time – 1,423 mg/kg (Table 2).

The nitrates content ranged from 293 to 3,817 mg per kg (Tables 1 and 2). In 1998, the levels of nitrate contents were statistically higher for lettuce from spring cultivation in comparison with summer time (Table 4). In 1999, the levels of nitrates content were statistically higher in autumn cultivation in compared to summer (Table 4). Higher levels of nitrates in lettuce from spring and autumn cultivation were triggered by lower intensity of light if compared to summer (Krezel, Koota 2003). The influence of year on nitrates content was statistically proved for lettuce cultivated in spring as well as in summer and autumn time (Table 5).

Weight of leaf rosette

In 1998 the highest weight of leaf rosette was reported for cv. Dubáček cultivated in summer time – 428 g (Table 1), and in 1999 for cv. Redin cultivated in summer time – 502 g (Table 2).

The leaf rosette weights ranged from 157 to 502 g (Tables 1 and 2). The differences were noted in cultivars (Table 3) among cultivation seasons (Table 4) and trial years (Table 5).

In 1998, the leaf rosette weight was statistically higher in lettuce from summer cultivation than from spring and autumn cultivation (Table 4). The weight of leaf rosette of cv. Redin was statistically higher in comparison with Lollo Rossa and Frisby cultivars (Table 3). In 1999, the weight of leaf rosette was statistically higher for lettuce from summer cultivation in comparison with autumn cultivation (Table 4).

The weights of leaf rosette for lettuce cultivated in summer time were statistically higher for cv. Redin and Bergamo in comparison with Lollo Rossa, Frisby and Dubáček cultivars (Table 3). There were statistically significant differences of leaf rosette weight in cultivars grown in the autumn term; higher weight was noted for Bergamo, Redin and Frisby than for Lollo Rossa cultivar (Table 3). The factors such as cultivation season, weather conditions and cultivar influenced the formation of phytomass of leaf rosette, which affected its total

Table 7. Weight of leaf lettuce rosette (g)

Cultivar	Spring			Summer			Autumn		
	1998	1999	average	1998	1999	average	1998	1999	average
Bergamo	288	213	251	387	283	335	297	187	242
Dubáček	271	466	369	428	459	444	302	284	293
Frisby	234	246	240	351	297	324	326	175	251
Lollo Rossa	198	234	216	336	277	307	216	164	190
Redin	347	423	385	424	502	463	328	245	287

weight. These results correspond to the results listed by KRAKER (1994), i.e. leaf rosettes reach weight up to 500 g.

CONCLUSION

The content of selected substances in lettuce and the weight of leaf rosettes ranged as follows: vitamin C (65 to 302 mg/kg), potassium (2,394 to 6,477 mg per kg), sodium (39 to 223 mg/kg), calcium (200 to 755 mg/kg), magnesium (110 to 413 mg/kg), fibre (4.98 to 12.22 g/kg), dry matter (59 to 140 g/kg), nitrates (293 to 3,817 mg/kg), and weight of leaf rosette (164 to 502 g).

The cultivar of leaf lettuce influenced significantly the content of K, Na, Ca, dry matter and the weight of leaf rosette.

The cultivation season influenced all the evaluated substances (besides fibre) as well as the weight of leaf lettuce rosette.

The year of cultivation influenced all the evaluated parameters, except for Ca.

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Nutriční látky u vybraného sortimentu odrůd listového salátu (*Lactuca sativa* L. var. *crispa*)

ABSTRAKT: Ve dvouletých pokusech, které probíhaly na Zahradnické fakultě v Lednici (Mendelova zemědělská a lesnická univerzita v Brně), bylo hodnoceno pět odrůd listového salátu (*Lactuca sativa* L. var. *crispa*) – Bergamo, Dubáček, Frisby, Lollo Rossa a Redin. Pokusy byly zakládány ve třech termínech (jarní, letní a podzimní) a ve dvou pokusných letech (1998 a 1999). Po sklizni byla hodnocena nutriční hodnota: obsah vitaminu C, minerálních látek (K, Na, Ca, Mg), vlákniny, sušiny a obsah dusičnanů. Byla také hodnocena hmotnost listových růžic. Byly zjištěny hodnoty obsahu vybraných látek a hmotnosti listové růžice v těchto intervalech: vitamin C (65 až 302 mg/kg), draslík (2 394 až 6 477 mg/kg), sodík (39 až 223 mg/kg), vápník (200 až 755 mg/kg), hořčík (110 až 413 mg/kg), vláknina (4,98 až 12,22 g/kg), sušina (59 až 140 g/kg), dusičnany (293 až 3 817 mg/kg) a hmotnost listové růžice (164 až 502 g). Průkazný vliv odrůdy byl zaznamenán v obsahu draslíku, sodíku, vápníku, sušiny a hmotnosti listové růžice. Termín pěstování průkazně ovlivnil všechny hodnocené ukazatele s výjimkou vlákniny, vliv roku nebyl průkazný pouze u obsahu Ca. Z výsledků je patrné, že sledované obsahové látky byly významně ovlivňovány jak odrůdou, tak i termínem pěstování a rokem.

Klíčová slova: listový salát (*Lactuca sativa* L. var. *crispa*); odrůdy; obsažené látky

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