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THEORETICAL AND PRACTICAL FOUNDATIONS OF THE UTILIZATION OF STINGING NETTLE (*URTICA DIOICA* L.) AS A VEGETABLE CROP

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1. INTRODUCTION

In addition to its role in subsistence, food has an effect on human health and general condition. A proper level of vegetable consumption is part of a healthy diet.

The level of vegetable supply is determined by the amount, structure and regularity of consumption. In Hungary, the amount of the consumed vegetables is acceptable. However, the structure and regularity of consumption are not satisfactory.

The present structure of the domestic vegetable consumption is narrow, the majority of consumption is given by only about ten vegetable species instead of the desirable 20-25 species. A wider array of products is more favourable as the wider product range ensures the necessary nutrients for the human body with a higher probability.

The regularity of fresh vegetable consumption is not satisfactory either, the majority of consumption is in the late summer and early autumn months. The most critical period for the regularity of vegetable consumption is in early spring, the fresh vegetable supply is the poorest at this time.

The enhancement of the vegetable consumption level (via the improvement of the three above factors) can be solved by increasing the volume of consumption, by providing a higher number of available vegetable species and an even supply during the course of the year. Those vegetables and special vegetables which can be harvested in early spring are especially favourable as they improve the structure and the regularity of vegetable consumption at the same time (they enlarge the vegetable assortment and reduce seasonality).

The research topic of the present thesis was the study of the utilization of stinging nettle (*Urtica dioica* L.) as an alternative food crop. Stinging nettle can be harvested (also) in early spring, therefore, it is suitable for both the enrichment of the product range and for improving the regularity of vegetable consumption. An argument for the utilization of stinging nettle as a food crop is that it is not ’overdomesticized’. It does not have pests of great significance (as is characteristic to the monoculture crops), therefore, it can be easily integrated into the non-conventional environmentally-benign production.

In our research, the main objective was to determine those components of stinging nettle which influence its nutritive value. After its preparation as a food, we also performed organoleptic tests.

2. MATERIALS AND METHODS

2.1. Establishment of the stinging nettle gene bank

When planning the examinations, a stinging nettle gene bank was established at the University of Debrecen Centre of Agricultural Sciences, so that the production and biological value of nettle plants originating from different places could be studied under the same ecological conditions. In the gene bank area, four rows were created with 36 stinging nettle plants per row. The plant material for the gene bank was collected in the autumn of 2003.

In Hungary, plants were collected from 24 locations: Bak, Baktüttős, Botfa, Bőcs, Bötefa (Alsónemesapáti), Debrecen, Deseda (Keszthely), Előhát (Tedej), Gemenc, Kisbucsa, Külsősárd, Nova, Pilis (Budakeszi), Porszombat, Pusztaederics, Rédics, Söjtör, Szakoly, Szentgyörgyvölgy-Nagymétnek, Tenkehegy (Lenti), Tőserdő (Lakitelek), Zalaszentiván, Zalaszentlőrinc, Zselic (Kaposvár).

The plants from abroad originated from: Tátra-Lomnic (Stara Lesna, Slovakia), Tampere, Mikkeli (Finland), Bredemann No. 3, Bredemann No. 8, Bredemann No. 9 (Germany).

After overwintering the plants in the greenhouse, planting in a randomised design was performed on 28 April 2004.

2.2. Materials and methods of the organoleptic tests

For the organoleptic tests, stinging nettle samples were collected twice from the gene bank from the taxons used in the laboratory examinations. After harvest, only the shoot tips with young leaves (as offered by the literature) were used. In the five organoleptic tests the following dishes were judged: 1. croquette with béchamel sauce flavoured with nettle and New-Zealand spinach, 2. nettle and spinach vegetable dishes, 3. cheese with nettle, celery leaves and chives leaves, 4. cheese with nettle, 5. potato croquette with nettle.

In the tests, the questions referred to the consistency, colour, flavour and based on these to the willingness to buying and consuming the products.

2.3. Materials and methods of the laboratory examinations

For the laboratory examinations, the plant samples were collected from the gene bank. The inner content components were studied in 3-4 plants of eight different 'variety groups' (1. Pilis; 2. Mikkeli, 3. Bredemann No. 3; 4. Bredemann No. 8, 5. Bredemann No. 9; 6. Tampere; 7. Tőserdő; 8. Gemenc) for three consecutive harvests. At the first harvest, the fresh shoots of the overwintered plants were available (19 April 2006), while at the second (15 May 2006) and third harvests (2 August 2006) re-sprouting shoots were used. After the harvest, similarly to the organoleptic tests, only the shoot tips with young leaves recommended for consumption were used.

Simultaneously with the examination of the inner content of nettle samples from the first harvest, comparative measurements were performed for spinach (variety: Matador, one repetition). This species was selected for comparison, because nettle is considered primarily as a substitute plant for spinach which is a valuable food crop.

In the laboratory examinations, the following inner content parameters were measured: 1. protein, 2. fiber, 3. calcium, 4. iron, 5. carotenoid, 6. vitamin C, 7. antioxidant capacity of water-soluble compounds (ACW), 8. antioxidant capacity of lipid-soluble compounds (ACL), 9. nitrate content.

The protein, fiber, calcium, iron, carotenoid vitamin C, ACW and ACL data were statistically evaluated separately for the locations ('variety group') and harvest dates. For the statistical analysis, data of the same three plants from a given location and harvest date (Table 1) were used.

Table 1. Plants included in the statistical analysis

'Variety group'	Location in the gene bank		
Pilis	B33	C12	D1
Mikkeli	A26	C2	C36
Bredemann No. 3.	A16	C21	D15
Bredemann No. 8.	A23	A32	C11
Bredemann No. 9.	B30	C1	C24
Tampere	B12	D3	D36
Tőserdő	A20	C16	C31
Gemenc	B14	B22	D4

At the second harvest, a smaller amount of biomass was obtained. The necessary examinations could not be performed on all of the plants and fiber content was not measured for any. Therefore, there are no data on fiber content for the second harvest, while for protein, calcium, iron, carotenoid, vitamin C measurements, the data of two plants are included, but no statistical evaluation was made. Water- and lipid-soluble antioxidant capacities could be measured also for the second harvest, so these data were analysed statistically.

The differences in inner content between the plants from different locations (’variety groups’) were evaluated by one-way analysis of variance. The significant differences were given at SD 5% probability level.

The differences between the different harvest dates (first and third, in the case of ACW and ACL: first, second and third) were also analysed by one-way analysis of variance at SD 5% probability level.

2.3.1. Measurement of protein content

For determining protein content, 3 g fresh sample was rubbed in a porcelain bowl with quartz sand by adding 1 ml Tris-HCl (pH 7.0) buffer, then it was diluted to 50 ml by adding distilled water to it in a flask. Then, the sample was filtered through a filter paper and 3 ml of the solution was centrifuged for 5 minutes at 10 000 rpm. After the centrifugation, the top layer was taken and photometered at 260 and 280 nm with a spectrophotometer (AMERSHAM BIOSCIENCES Ultrospec 2100 pro). From the measured absorbance value, the protein content was calculated according to the formula.

2.3.2. Measurement of fiber content

For determining the fiber content, 3 g fresh sample was rubbed in a porcelain bowl by adding 50 ml 9 % hydrochloric acid (HCl). Then it was boiled in an Erlenmeyer flask in water bath for 30 minutes. After sieving, it was dried on filter paper until becoming air-dry and measured again. The fiber content was determined from the initial and final mass.

2.3.3-2.3.4. Measurement of the calcium and iron content

For determining the calcium and iron content, the samples were lyophilized and pulverized. The remaining water was removed in a drying closet at 105°C. The dust samples were prepared for measurement by atmospheric wet destruction. 5 cm^3 65 % (m/m) nitric acid and 1 cm^3 30 % (m/m) hydrogene-peroxid were added to the samples and they were heated at 80°C on a boiling plate. The obtained extracts were diluted to 10 cm^3 final volume. The ICP-OES measurements were performed with an Iris Intrepid II Duo xSP equipment (Thermo Electron Corporation, Germany).

2.3.5. Measurement of the carotenoid content

For determining the carotenoid content – and chlorophyll A and B – 3 g fresh sample was measured into a 25 ml volumetric flask and diluted with 80 % acetone to 25 ml. The sample was left to stand for 30 minutes and was shaken regularly, then 10 ml of the solution was centrifuged for 5 minutes at 10 000 rpm. After the centrifugation, the top layer was removed and photometered at 664, 644 and 480 nm with a spectrophotometer (AMERSHAM BIOSCIENCES Ultrospec 2100 pro). From the measured absorbance value, the carotenoid content was calculated according to the formula.

2.3.6. Measurement of the vitamin C content

For determining the vitamin C content, 5 g of the sample was measured on an analytical scale and placed into a porcelain bowl. For conserving the ascorbic acid, 1 ml of acidum aceticum was added, then it was pulpified. The pulp was washed into 100 ml flasks and diluted to 100 ml with distilled water then shaken. From the shaken solution, 50 ml was sieved through a sieving paper into a 100 ml Erlenmeyer flask. From this extract, the apparent ascorbic acid content and the amount of reductive compounds were determined.

Determination of the apparent ascorbic acid content: 10 ml of the plant extract (prepared as described above), 10 ml distilled water, 3 ml 10% phosphoric acid, 2.5 ml α,α'-dipiridil reagent and 1 ml 10 % $FeCl_3$ solution were measured into a 100 ml volumetric flask. The content of the flask was shaken after adding each reagent. Then it

was left to stand in darkness for 30 minutes. After the 30 minutes, it was diluted with distilled water to 100 ml, then shaken and photometered at 496 nm.

Determination of the reductive compounds: 2 ml of the plant extract (prepared as above), 10 ml distilled water and 5 ml 5 % ammonium-acetate was measured into a 100 ml volumetric flask. The flask was put into a 50°C water bath for 30 minutes. After 30 minutes, 30 ml distilled water was added, it was cooled, then 20 ml 4 % trichlor-acetic acid was added. Then, 2.5 ml 10% phosphoric acid, 2.5 ml α,α'-dipiridil reagent and 1 ml 10 % $FeCl_3$ solution were added to it. The content of the flask was shaken after adding each reagent. Then it was left to stand in darkness for 30 minutes. After the 30 minutes, it was diluted with distilled water to 100 ml, then shaken and photometered at 496 nm.

The apparent ascorbic acid content and the amount of reductive compounds were calculated according to the formulas. The actual amount of ascorbic acid was calculated as the difference between the amount of apparent ascorbic acid and the reductive compounds.

2.3.7-2.3.8. Measurement of the antioxidant capacity of water-soluble compounds (ACW) and the antioxidant capacity of lipid-soluble compounds (ACL)

For determining the antioxidant capacity of water-soluble compounds (ACW) and the antioxidant capacity of lipid-soluble compounds (ACL), the method of photochemiluminescence was applied using a PHOTOCHEM® (Analytik Jena AG, Germany) photochemiluminometer.

The sample was prepared by freezing 5 g fresh sample to -70°C which was then lyophilized. After lyophilisation, the sample was pulverized. From the water-free dust, 10 mg was dissolved in 1 ml bidistilled water under continuous mixing for 60 seconds. Then, it was centrifuged at 10 000 rpm for 5 minutes, then the top layer was sucked. The sample prepared in this way was used and further diluted.

For determining the antioxidant capacity of water-soluble compounds (ACW) L-ascorbic acid standard of 0; 0.2; 0.5; 0.8; 1.0; 2.0; 3.0 nmol concentration was used and the calibration was done for this. The measurement period was 250 seconds. The values obtained in nmol were given as $\mu g\ mg^{-1}$ ascorbic acid equivalent, which gives the density of water-soluble antioxidants in the sample expressed as a unit of standard equivalence.

For determining the antioxidant-capacity of lipid-soluble compounds (ACL), an α-tocopherol standard of 0; 0.2; 0.5; 0.8; 1.0; 2.0; 3.0 nmol concentration was used and the calibration was made for this. The measurement time was 180 seconds. The values obtained in nmol were given as μg mg^{-1} trolox equivalent, which gives the density of lipid-soluble antioxidants in the sample expressed as a unit of standard equivalence.

2.4. Determination of the revised average nutritive value of stinging nettle

The calculation of the revised average nutritive value was done based on the average nutritive value index (ANV) of GRUBBEN (1977). From the six factors constituting the average nutritive value index, one was modified, instead of carotene, carotenoid content was measured and used for the calculations. We considered it important to modify this factor, because in addition to carotene, the other carotenoid compounds also have a significant role in nutrition and health preservation. The carotenoid values were divided by one hundred for easier calculation. Revised average nutritive value (RANV) in 100 g consumed part:

$$\mathrm{RANV} = \frac{\text{protein (g)}}{5} + \text{fiber (g)} + \frac{\text{calcium (mg)}}{100} + \frac{\text{iron (mg)}}{2} + \frac{\text{carotenoid (mg)}}{100} + \frac{\text{vitamin C (mg)}}{40}$$

3. RESULTS AND DISCUSSION

3.1. Results of the organoleptic examinations

In the organoleptic tests, one of the best known preparation forms, the nettle vegetable dish was the least preferred by the judges. The croquettes flavoured with nettle (in béchamel sauce and made from potato) had a more favourable reception. The most preferred nettle product was the cheese with nettle. Based on the organoleptic tests it can be stated that products of similar colour, consistence and flavour can be prepared from nettle and spinach (and New-Zealand spinach), but the colour of nettle foods is darker. The high fiber content and the nettle hairs can reduce the deliciousness of the food as they create a sense of ’sand in the food’. Another characteristic of nettle foods is their ’fish-like after-taste’.

Stinging nettle, considered as a plant for substituting spinach, cannot only be prepared as a soup or a vegetable dish, especially as it is not likely to spread widely in this form. Those foods can be much more popular in which nettle is used as a seasoning material as was confirmed by the results of our organoleptic tests. In addition to the studied croquettes and cheese with nettle, further foods with nettle are imaginable such as bread, pastry, pasta, omelette, sandwich cream. Nettle leaves do not sting after a thorough rinsing (after ’rubbing’ the nettle hairs), so it can be a valuable fresh component of salads.

3.2. Results of the laboratory examinations

3.2.1. Protein content

The results of the protein content measurements are included in Table 2. The average protein content values for the first harvest varied between 4.63 and 7.00 g for 100 g consumed part. The highest average values were obtained for the ’variety groups’ Tőserdő and Bredemann No. 3. Their values were significantly different from those of the Mikkeli, Bredemann No. 8, Bredemann No. 9 and Pilis ’variety groups’, while the differences from the Gemenc and Tampere ’variety groups’ were not significant.

For spinach, the average value measured simultaneously with the first harvest of nettle was 1.91 g 100 g^{-1}. Namely, the protein content of nettle was several times higher than that of spinach.

Table 2. Results of the protein content measurements (Debrecen, 2006)

'Variety group'	Protein (g 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest**	3rd harvest*
Pilis	4.63c±0.41	5.12±1.07	9.44ab±2.20
Mikkeli	4.98bc±0.65	4.13±1.23	4.39d±0.98
Bredemann No. 3.	6.66a±0.25	6.92±0.20	6.82c±0.78
Bredemann No. 8.	4.84c±1.48	6.50±0.86	8.95bc±1.51
Bredemann No. 9.	4.70c±0.64	3.74±0.42	10.47ab±0.65
Tampere	5.73abc±1.16	5.30±2.73	6.41d±0.93
Tőserdő	7.00a±1.63	7.49±0.71	8.50bc±2.01
Gemenc	6.39ab±1.38	7.22±0.12	11.37a±0.65
SD 5%	**1.43**	**-**	**2.02**
Spinach (Matador)	*1.91±0.69*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
**No statistical evaluation was performed

For the third harvest, the average protein content values ranged between 4.39 and 11.37 g 100 g^{-1}, with the lowest and highest values for the 'variety groups' Mikkeli and Gemenc, respectively. The results of the 'variety group' Gemenc with the highest protein content were not significantly different from those of the 'variety groups' Bredemann No. 9 and Pilis. However, they were significantly different from the 'variety groups' Bredemann No. 8, Tőserdő, Bredemann No. 3, Tampere and Mikkeli. The lower values measured at the third harvest (except for the 'variety group' Mikkeli) would have been considered high at the first and second harvest dates.

The statistical analysis of the average values for the first and third harvests justified that there was a significant difference between the average value of the third harvest (8.29 g 100 g^{-1}) and the average value of the first harvest (5.62 g 100 g^{-1}) (SD 5% = 1.57 g 100 g^{-1}).

3.2.2. Fiber content

The results of the fiber content measurements are presented in Table 3. For the first harvest, we measured average values between 9.61 and 11.14 g 100 g^{-1} (consumed part). The lowest and highest fiber content was measured for the 'variety groups' Bredemann No. 8 and Bredemann No. 3, respectively. There were no significant differences between the results of the eight 'variety groups'.

For spinach, the average value measured simultaneously with the first harvest of nettle was 3.39 g 100 g^{-1} meaning that the fiber content of nettle was several times higher than that of spinach.

Table 3. Results of the fiber content measurements (Debrecen, 2006)

'Variety group'	Fiber (g 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest	3rd harvest*
Pilis	10.61a±1.50	nd	14.77abc±3.72
Mikkeli	10.24a±1.04	nd	12.84c±1.93
Bredemann No. 3.	11.14a±1.25	nd	16.47a±1.58
Bredemann No. 8.	9.61a±0.84	nd	14.54abc±0.69
Bredemann No. 9.	9.97a±0.74	nd	15.50ab±1.33
Tampere	10.40a±1.46	nd	15.69ab±2.00
Tőserdő	10.71a±1.16	nd	13.40bc±1.01
Gemenc	10.94a±0.48	nd	15.49ab±1.20
SD 5%	**1.83**	**-**	**2.54**
Spinach (Matador)	*3.39±0.42*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
nd = no data available

For the third harvest, even higher values were measured. The highest fiber content was measured for the 'variety group' Bredemann No. 3 also in this case (16.47 g 100 g^{-1}). However, its value was significantly different only from that of the 'variety group' Mikkeli. It should be noted that even the lowest fiber content of the Mikkeli 'variety group' (12.84 g 100 g^{-1}) was higher than the value of Bredemann No. 3 'variety group' which was the highest at the first harvest (11.14 g 100 g^{-1}).

The statistical analysis of the average data obtained at the first and third harvests that there was a significant difference between the average value of third harvest (14.84 g 100 g^{-1}) and the first harvest (10.45 g 100 g^{-1}) (SD 5% = 2.11 g 100 g^{-1}).

3.2.3. Calcium content

Results of the calcium content measurements are presented in Table 4. At the first harvest date, the highest average value was obtained for the 'variety group' Pilis (887.59 mg 100 g^{-1}), however, this was significantly different only from the results of the 'variety groups' Mikkeli and Bredemann No. 3 (689.37, and 647.08 mg 100 g^{-1}).

For spinach, an average value of 115.75 mg 100 g^{-1} was measured. Consequently, the calcium content of spinach was only a fraction of that of the nettle plants from different locations.

Table 4. Results of the calcium content measurements (Debrecen, 2006)

'Variety group'	Calcium (mg 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest**	3rd harvest*
Pilis	887.59a±52.13	716.07±77.57	990.77b±248.83
Mikkeli	689.37b±98.75	572.03±77.18	1077.68ab±90.02
Bredemann No. 3.	647.08b±100.06	481.41±27.13	988.06b±83.91
Bredemann No. 8.	794.47ab±73.81	623.28±94.57	1004.13b±131.30
Bredemann No. 9.	801.29ab±156.80	695.03±39.90	1122.39ab±168.18
Tampere	743.07ab±112.66	618.11±20.07	1308.86a±399.72
Tőserdő	763.11ab±220.66	768.61±251.79	943.09b±101.32
Gemenc	736.75ab±46.99	606.12±309.32	933.65b±114.35
SD 5%	**190.93**	**-**	**269.89**
Spinach (Matador)	*115.75±8.58*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
** No statistical evaluation was performed

For the third harvest, considerably higher values were obtained. Even for the 'variety group' Gemenc having the lowest calcium content, the average value was 933.65 mg 100 g^{-1} which is higher than the highest value measured in the first harvest. The result of the 'variety group' Gemenc was significantly different only from that of the 'variety group' Tampere with the highest calcium content (1308.86 mg 100 g^{-1}).

The average value of the third harvest (1046.08 mg 100 g^{-1}) was significantly higher than that of the first harvest (757.84 mg 100 g^{-1}) (SD 5% = 189.32 mg 100 g^{-1}).

3.2.4. Iron content

The results of the iron content measurements are included in Table 5. For the first harvest, the average values varied between 2.13 and 5.98 mg 100 g^{-1}. The lowest and highest iron content was measured for the 'variety groups' Bredemann No. 8 and Bredemann No. 3, respectively. The results of the 'variety group' Bredemann No. 3 were not significantly different from those of the 'variety groups' Tampere and Mikkeli, but they were significantly different from the values of the 'variety groups' Gemenc, Tőserdő, Bredemann No. 9, Pilis and Bredemann No. 8.

For spinach, we have obtained an average value of 2.21 mg 100 g^{-1} when measuring iron content simultaneously with the first harvest of nettle. The result of the 'variety group' Bredemann No. 8 with the lowest iron content was slightly lower than this.

Table 5. Results of the iron content measurements (Debrecen, 2006)

'Variety group'	Iron (mg 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest**	3rd harvest*
Pilis	2.80c±0.16	5.72±2.35	1.98b±0.73
Mikkeli	4.51ab±1.24	4.38±1.59	4.92a±0.95
Bredemann No. 3.	5.98a±3.98	4.67±2.04	3.37ab±1.77
Bredemann No. 8.	2.13c±0.38	3.50±1.39	2.58b±0.16
Bredemann No. 9.	2.85c±1.18	5.83±4.17	1.89b±0.19
Tampere	5.38a±0.84	3.37±0.16	2.34b±1.06
Tőserdő	3.05bc±1.27	4.08±2.01	2.74ab±1.35
Gemenc	3.32bc±1.30	3.76±0.21	1.94b±0.35
SD 5%	**1.63**	**-**	**2.30**
Spinach (Matador)	*2.21±0.16*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
** No statistical evaluation was performed

The average iron content values at the third harvest ranged between 1.89 and 4.92 mg 100 g^{-1}. The lowest and highest values were obtained for the 'variety groups' Bredemann No. 9 and Mikkeli, respectively. The result of the 'variety group' Mikkeli with the highest iron content was significantly different from that of the 'variety groups' Bredemann No. 9, Gemenc, Pilis, Tampere and Bredemann No. 8, but it was not

significantly different from the values of the 'variety groups' Tőserdő and Bredemann No. 3.

Based on the results of the first and third harvests the iron content of the samples from more mature plants is lower. The average values of the first and third harvests were 3.75 mg 100 g^{-1} and 2.72 mg 100 g^{-1}, respectively. There was a significant difference between the two values (SD 5% = 0.97 g 100 g^{-1}).

3.2.5. Carotenoid content

The results of the carotenoid content measurements are presented in Table 6. For the first harvest, the average values ranged between 451.67 and 806.47 mg 100 g^{-1}, the lowest and highest values were measured for the 'variety groups' Tampere and Bredemann No. 8. The average value of the Bredemann No. 8 was significantly different from all other 'variety groups' except for Bredemann No. 9. The value of the 'variety group' Tampere was significantly different only from that of the 'variety groups' Bredemann No. 8 and Bredemann No. 9.

For spinach, we have obtained an average value of 340.14 mg 100 g^{-1} when measuring carotenoid content simultaneously with the first harvest of nettle. Even the average values of plants with the lowest carotenoid content from Tampere were 1.5 times higher than those of spinach.

Table 6. Results of the carotenoid content measurements (Debrecen, 2006)

'Variety group'	Carotenoid (mg 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest**	3rd harvest*
Pilis	592.32bc±49.98	669.99±151.77	1072.70ab±159.86
Mikkeli	584.78bc±55.46	534.35±209.30	618.17c±14.45
Bredemann No. 3.	457.30c±34.63	407.54±44.25	1338.81a±270.43
Bredemann No. 8.	806.47a±156.20	535.93±26.71	1058.52b±301.57
Bredemann No. 9.	670.14ab±228.60	303.50±1.86	518.56c±93.64
Tampere	451.67c±115.50	548.36±312.65	1127.50ab±25.71
Tőserdő	612.99bc±66.37	546.72±278.01	1043.62b±174.51
Gemenc	599.49bc±93.44	647.66±92.11	1214.76ab±159.23
SD 5%	**177.64**	**-**	**251.12**
Spinach (Matador)	*340.14±22.83*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
** No statistical evaluation was performed

For the third harvest, the average values were mostly above 1000 mg 100 g^{-1}. Lower carotenoid contents were measured only for the 'variety groups' Bredemann No. 9 and Mikkeli (518.56, and 618.17 mg 100 g^{-1}). The two values were not significantly different from each other, but they were significantly different from the results of all other 'variety groups'.

The average of the results at the first harvest was 596.90 mg 100 g^{-1}, while the average of the third harvest was significantly higher, 999.08 mg 100 mg^{-1} (SD 5% = 248.22 g 100 g^{-1}).

3.2.6. Vitamin C content

The results of the vitamin C content measurements are presented in Table 7. Vitamin C content values for the first harvest ranged between 17.22 and 46.34 mg 100 g^{-1} with the lowest values for the 'variety group' Mikkeli and the highest values for Tőserdő. The average value of the 'variety group' Tőserdő was significantly different from that of the 'variety groups' Gemenc, Pilis, Bredemann No. 8, Bredemann No. 9 and Mikkeli.

Simultaneously with the first harvest, comparative measurements were made with spinach for vitamin C content also. For spinach, an average value of 78.64 mg per 100 g consumed part was measured. This was higher than the vitamin C content of nettle.

For the third harvest, the vitamin C content ranged between 23.79 and 69.14 mg per 100 g consumed part. The highest value was obtained for the 'variety group' Mikkeli, the result was significantly different from that of the 'variety groups' Pilis, Bredemann No. 3, Gemenc, Bredemann No. 8 and Bredemann No. 9 with the lowest vitamin C content.

When analysing the results of the first and third harvests, it can be stated that the average of the results was higher for the third harvest. The average of the first harvest was 29.38 mg 100 g^{-1}, while for the third harvest it was 42.79 mg 100 g^{-1}. There was a significant difference between the two values (SD 5% = 11.72 mg 100 g^{-1}).

Table 7. Results of the vitamin C content measurements (Debrecen, 2006)

'Variety group'	Vitamin C (mg 100 g^{-1} fresh weight)		
	1st harvest*	2nd harvest**	3rd harvest*
Pilis	24.08bc±6.82	48.99±19.34	43.30b±18.05
Mikkeli	17.22c±3.69	25.92±15.14	69.14a±9.69
Bredemann No. 3.	41.37a±8.28	43.38±9.55	36.68bc±23.45
Bredemann No. 8.	22.22bc±1.05	28.99±6.72	33.31bc±11.23
Bredemann No. 9.	20.70c±5.60	27.33±18.43	23.79c±3.27
Tampere	34.85ab±6.24	17.83±6.37	51.25ab±16.33
Tőserdő	46.34a±11.65	42.40±17.60	51.08ab±10.34
Gemenc	28.26bc±10.57	37.65±3.67	33.79bc±3.75
SD 5%	**12.97**	**-**	**18.32**
Spinach (Matador)	*78.64±14.14*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
** No statistical evaluation was performed

3.2.7. Antioxidant capacity of water-soluble compounds (ACW)

The results of the measurements on the antioxidant capacity of water-soluble compounds (ACW) are presented in Table 8. The values of the first harvest ranged between 6.73 and 35.43 μg mg^{-1} d.m. (ascorbic acid equivalence) with the lowest and highest valued for the 'variety group' Mikkeli and Tőserdő, respectively. The results of the 'variety group' Tőserdő were significantly different only from those of the 'variety groups' Pilis and Mikkeli.

In the measurements performed simultaneously with the first harvest, an average value of 2.86 μg mg^{-1} was obtained for spinach. The antioxidant capacity of water-soluble compounds (ACW) was several times higher in nettle.

For the samples from the second harvest, considerably lower values were measured. The lowest average values were again obtained for the 'variety group' Mikkeli (0.60 μg mg^{-1}), while the highest values were for the 'variety group' Bredemann No. 3 (3.06 μg mg^{-1}). The values of the 'variety group' Bredemann No. 3 were significantly different from those of the 'variety groups' Pilis, Bredemann No. 8, Bredemann No. 9 and Mikkeli.

Table 8. Results of the measurements on the antioxidant capacity of water-soluble compounds (ACW) (Debrecen, 2006)

'Variety group'	ACW μg mg^{-1} d.m. (ascorbic acid equivalence)		
	1st harvest*	2nd harvest*	3rd harvest*
Pilis	8.49b±2.72	0.82b±0.38	10.52ab±2.38
Mikkeli	6.73b±2.62	0.60b±0.31	2.67b±2.46
Bredemann No. 3.	28.11ab±18.53	3.06a±1.50	1.23b±0.46
Bredemann No. 8.	13.78ab±6.21	0.70b±0.25	21.78a±18.22
Bredemann No. 9.	21.12ab±5.62	0.63b±0.12	9.39ab±4.52
Tampere	19.22ab±16.36	1.51ab±0.22	1.40b±0.47
Tőserdő	35.43a±19.48	1.48ab±0.96	21.50a±17.48
Gemenc	21.47ab±14.26	nd	0.95b±0.15
SD 5%	**21.88**	**1.25**	**15.84**
Spinach (Matador)	*2.86±0.08*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
nd = no data available

In the third harvest, the average values varied between 0.95 and 21.78 μg mg^{-1} with the lowest and highest values for the 'variety groups' Gemenc and Bredemann No. 8, respectively. The values of the 'variety group' Bredemann No. 8 were significantly different from those of the 'variety groups' Gemenc, Bredemann No. 3, Tampere and Mikkeli.

Comparing the results of the three harvests, it can be stated that there are considerable differences among them. The largest antioxidant capacity of water-soluble compounds were observed at the first harvest (19.29 μg mg^{-1}), followed by the result of the third harvest (8.68 μg mg^{-1}), while the lowest value was obtained for the second harvest (1.26 μg mg^{-1}). The differences among the harvests were significant (SD 5% = 2.67 μg mg^{-1}).

3.2.8. Antioxidant capacity of lipid-soluble compounds (ACL)

The results of the measurements on the antioxidant capacity of lipid-soluble compounds are included in Table 9. The lowest and highest values for the first harvest were measured for the 'variety groups' Tampere (22.97 μg mg^{-1}) and Gemenc (41.55 μg mg^{-1}), respectively. The results of the 'variety group' Gemenc were significantly different from those of the 'variety groups' Pilis, Mikkeli and Tampere.

In the comparative measurements performed simultaneously with the first harvest, we obtained an average value of 11.84 μg mg^{-1} for spinach. Accordingly, the antioxidant capacity of lipid-soluble compounds (ACL) was several times higher in nettle than in spinach.

Table 9. Results of the measurements on the antioxidant capacity of lipid-soluble compounds (ACL) (Debrecen, 2006)

'Variety group'	ACL μg mg^{-1} d.m. (trolox equivalence)		
	1st harvest*	2nd harvest*	3rd harvest*
Pilis	29.88bc±6.30	1.59c±0.24	4.67a±0.22
Mikkeli	26.76bc±6.33	1.64c±0.30	6.72a±4.23
Bredemann No. 3.	40.45a±7.55	4.01a±0.96	4.72a±0.89
Bredemann No. 8.	35.60ab±1.70	2.52bc±0.47	8.74a±3.09
Bredemann No. 9.	33.04abc±1.63	1.84c±0.04	7.69a±4.20
Tampere	22.97c±6.31	3.17ab±0.26	4.26a±2.05
Tőserdő	35.87ab±3.15	2.54bc±0.87	6.80a±2.70
Gemenc	41.55a±9.37	nd	5.71a±2.29
SD 5%	**10.24**	**0.97**	**4.84**
Spinach (Matador)	*11.84±0.70*		

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level
nd = no data available

At the second harvest, considerably lower values were measured. The average values ranged between 1.59 and 4.01 μg mg^{-1}, the lowest and highest were for the 'variety groups' Pilis and Bredemann No. 3. The results of the 'variety group' Bredemann No. 3 were significantly different from those of all the other 'variety groups' except for Tampere.

At the third harvest, the lowest and highest values were obtained for the 'variety groups' Pilis (4.67 μg mg^{-1}) and Bredemann No. 8 (8.74 μg mg^{-1}), respectively, however, there was no significant difference between them.

The trends of the results for the antioxidant capacity of lipid-soluble compounds (ACL) were similar to those of the antioxidant capacity of water-soluble compounds (ACW). The highest average values were obtained at the first harvest, followed by the values of the third harvest, the lowest being those of the second harvest. The average values were 33.27 μg mg^{-1}, 2.47 μg mg^{-1} and 6,16 μg mg^{-1} for the first, second and third harvests, respectively. The values of the first harvest were significantly different from

those of the second and third harvests. There was no significant difference between the values of the second and third harvests (SD 5% = 6.11 μg mg^{-1}).

3.3. The revised average nutritive value (RANV) of stinging nettle

The revised average nutritive value (RANV) of the stinging nettle plants from the different locations (’variety groups’) are presented in Table 10.

Table 10. The revised average nutritive value of stinging nettle (RANV)
(Debrecen, 2006)

’Variety group’	Revised average nutritive value (RANV)	
	1st harvest*	3rd harvest*
Pilis	28.33a±0.82	39.37abc±8.28
Mikkeli	26.66a±1.53	34.87c±2.07
Bredemann No. 3.	27.54a±3.27	43.71a±3.72
Bredemann No. 8.	28.21a±1.32	39.08abc±3.46
Bredemann No. 9.	27.57a±4.56	35.54c±0.34
Tampere	27.05a±2.17	43.78a±3.10
Tőserdő	28.55a±3.26	37.62bc±2.02
Gemenc	27.95a±0.36	41.07ab±0.80
SD 5%	**2.64**	**5.39**
Spinach (Matador)	*11.39±0.19*	

The values are given in the form average±deviation
*Significance: the average values indicated with at least one common letter are not significantly different from each other at $p<0.05$ level

The revised average nutritive values (RANV) calculated from the inner content parameters at the first harvest were nearly the same, ranging between 26.66 and 28.55 the lowest and the highest being those of the ’variety groups’ Mikkeli and Tőserdő. There was no significant difference between the two values.

Higher values were obtained for the third harvest and the differences between the average values were also larger. The lowest value was measured for the ’variety group’ Mikkeli again (34.87), while the highest was measured for Tampere (43.78). The results of the ’variety group’ Tampere were significantly different from those of the ’variety groups’ Tőserdő, Bredemann No. 9 and Mikkeli.

The averages of the first and third harvests (calculated from the values of the eight ’variety groups’) were 27.73 and 39.38, respectively. So, using the shoot tips of

more mature plants (third harvest), higher inner content parameters were measured, accordingly, the calculated revised average nutritive values were also higher. Comparing the result with that of spinach (11.39), it can be stated that the revised average nutritive value (RANV) of nettle was considerably higher than that of spinach which is considered a valuable vegetable crop.

4. NOVEL SCIENTIFIC RESULTS

1. For three harvests, we determined the protein, fiber, calcium, iron, carotenoid and vitamin C contents of eight stinging nettle 'variety groups' (Pilis, Mikkeli, Bredemann No. 3, Bredemann No. 8, Bredemann No. 9, Tampere, Tőserdő, Gemenc) harvested from the gene bank of the University of Debrecen Centre of Agricultural Sciences (first in the region) set up by collecting plants from abroad and Hungary. Simultaneously with the first harvest, comparative measurements were performed for spinach also.
2. We proved that the protein, fiber, calcium, iron and carotenoid contents of stinging nettle are higher than those of spinach, it was inferior to spinach only regarding the vitamin C content.
3. We found that the protein, fiber, calcium, carotenoid and vitamin C contents of stinging nettle plants are lower at the first spring harvest than those of the re-sprouted mature plants at the later harvest, only the iron content was higher at the first harvest.
4. We created a revised average nutritive value (RANV) index based on the average nutritive value (ANV) index of GRUBBEN (1977).
5. We proved that the revised average nutritive value (RANV) of stinging nettle is several times higher than that of spinach considered as a plant of great nutritional value by the literature.
6. We found that the revised average nutritive value of re-sprouted, mature stinging nettle plants at a later harvest is larger than that of plants at the first spring harvest.
7. We were the first to examine the antioxidant capacities of water-soluble (ACW) and lipid-soluble (ACL) compounds of eight stinging nettle 'variety groups' at three harvest dates with a PHOTOCHEM® instrument. Simultaneously with the first harvest, comparative measurements were made also for spinach.
8. We found that the antioxidant capacities of water-soluble (ACW) and lipid-soluble (ACL) compounds are several times higher at the first spring harvest in stinging nettle than in spinach.
9. We found that the antioxidant capacity of water-soluble compounds (ACW) and the antioxidant capacity of lipid-soluble compounds (ACL) follow a similar trend for the three consecutive harvests. The highest ACW and ACL values are characteristic to the first spring harvest. The lowest ACW and ACL values are obtained at the

second harvest, while the values of the third harvest are between the results of the first and second harvests.

5. RESULTS FOR PRACTICAL UTILIZATION

1. Stinging nettle can be harvested (also) in early spring, therefore, it is suitable for both for improving the structure and regularity of vegetable consumption as an alternative vegetable crop (it can enlarge the vegetable assortment and reduce seasonality).
2. It is not an ’overdomesticized’ plant. It does not have pests of great significance (as is characteristic to the monoculture crops), therefore, it can be easily integrated into the non-conventional environmentally-benign production.
3. In organoleptic tests, we studied the possibilities of its utilization as a food. We found that it can be successful primarily for food enrichment.
4. It sprouts well. It can provide fresh green leaves several times during a season from several harvests. Even its utilization as a fresh food by keeping it in containers (in the flat in the winter) is imaginable.
5. The consumption of the crop from the first spring harvest is the most beneficial. Although the revised average nutritive value is not the highest in the plant material from the first harvest, but both the antioxidant capacity of the water-soluble compounds (ACW) and the antioxidant capacity of the lipid-soluble compounds (ACL) are the largest at this time and the fresh vegetable supply is the poorest in spring in Hungary.

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