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# *Atriplex hortensis* L. as a leafy vegetable, and as a leaf protein concentrate plant

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**Abstract.** The quality of *Atriplex hortensis* L. (Mountain Spinach) as a leafy vegetable, forage crop, and plant for production of leaf protein/nutrient concentrate was investigated. The plant can substitute or supplement *Spinacia oleracea* L. as a leafy vegetable, due to similar chemical composition and a higher leaf yield. The whole plant, as a meal, is similar to *Medicago sativa* L. in chemical composition. It could be suitable for cultivation in dry areas. By wet-fractionation of the plant a leaf protein concentrate can be obtained. The concentrate is well composed, and should lack anti-nutritive substances present in the whole plant.

## Introduction

*Atriplex hortensis* L. is known in the international literature as Mountain Spinach, Garden Orache or Arrach, Arroche and Gartenmelde [7]. The plant was found to be an outstanding crop for production of leaf protein [2]. In the present paper qualitative aspects of the plant as a leafy vegetable, forage and plant for production of leaf protein/nutrient concentrate are given.

## Material and methods

Data on cultivation of the plant, its processing, its chemical analysis, and *in vivo* evaluation of it and of leaf protein concentrate from the plant are given in detail by Carlsson [2, 3], Carlsson et al. [5,6], Carlsson and Hallqvist [7] and Cheeke and Carlsson [8]. Chemical analysis is based on duplicate tests with standard deviation (SD) less then ± 3%.

## Results and discussion

### *Leafy vegetable.*

*Atriplex hortensis* L. was compared to *Spinacia oleracea* L. as a leafy vegetable, as enthusiastic home-growers had obtained good results (high yields, favourable organo-leptic properties). In different regions and with different fertilizers, the two species were compared [7]. The fresh weight of leaves, their dry weight and the crude protein amount in the leaves, were always higher for *A. hortensis* than for *S. oleracea* (2.4, 0.3, 0.08 kg/m$^2$ and 0.6, 0.06, 0.02 kg/$m^2$, respectively), when leaf harvest seemed optimal, i.e., before shooting (*A. hortensis* 10 wks, *S. oleracea* 7 wks). The contents of leaf dry matter were similar 12.9 and 11.7%, respectively, of the fresh weight. Leaves of both plants had similar mineral compositions, apart from a higher content of Fe and Zn in *S. oleracea,* and a higher content of $NO_3$-N in *A. hortensis* (Table 1). Blanching reduced the contents of several components, e.g., oxalic acid and nitrate (Table 1). The high yield of *A. hortensis* leaves, and a prolonged harvest season justified the use of this plant as a substitute, or supplement to *S. oleracea* as a 'spinach'. The production of a leaf protein/nutrient concentrate from *A. hortensis* can be recommended as soluble oxalic acid and nitrate are likely to be washed off during the production of the concentrate.

*Leaf meal for animal feed.*

Several Atriplex species are known as drought hardy forages [9, 10]. *A. hortensis* also seemed to be a potential forage crop due to its high yield of dry matter, up to 14 tonnes/ha, and of true protein, up to 1200 kg/ha, at a plant age of 14 weeks [2, 3]. Therefore, Cheeke and Carlsson [8] studied the whole plant meal composition. The chemical composition of the meal and the composition of its cell wall constituents indicated that it was comparable to *Medicago sativa* L. leaf meal. On the other hand, a study of the leaf meal of *A. hortensis* as a non-ruminant feed in a rat assay indicated that some anti-nutritive substances disturbed the rats [8]. Secondary plant substances as saponins, phenolics or oxalic acid might have disturbed the rats. As *Atriplex* species are grazed or browsed by ruminants a leaf meal of *A. hortensis* for cattle would not present any problem as a dried forage.

*Leaf protein/nutrient concentrate.*

By wet-fractionation a crop can be separated into a green, expressed juice and a pressed crop residue. From the juice a leaf protein/nutrient concentrate can be obtained by coagulating its protein, which causes a co-precipitation of other leaf nutrients. The concentrate is separated and washed, before drying into a storable product. In the juice of *A. hortensis* 60% of the plant true protein was extracted. Thus about 720 kg of the 1200 kg true protein produced per ha of *A. hortensis* was obtained in the concentrate. By fractionating extracted leaf protein into green and non-green fractions by heat [2, 3, 14] or by ultra-filtration [14] 25 respectively 30% of extracted protein were obtained in white leaf protein concentrates, about 200 kg protein per ha. White leaf protein normally has a nutritive value similar to milk protein [1]. Functional properties of white protein concentrate depend on its processing conditions.

Whole leaf protein/nutrient concentrate from *A. hortensis* contained about 60% true protein, less than 10% lipids, much beta-carotene compared to leaf, and valuable minerals and vitamins. The lipids contained much of

Table 1. Contents of nitrogenous substances, major and minor elements, and oxalic acid (% of DM)

| Type of material | | TN | $NO_3$-N | K | Mg | Ca | Fe | Mn | Cu | Zn | Oxalic acid | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lund: | | | | | | | (mg per kg) | | | | Total | Soluble |
| A. hortensis | A | 5.1 | 0.25 | 2.6 | 0.74 | 2.0 | 215 | 32 | 12 | 83 | 9.1 | 4.2 |
| | B | 5.2 | 0.15 | 1.7 | 0.48 | 3.3 | 190 | 25 | 15 | 80 | 6.9 | 2.9 |
| S. oleracea | A | 4.5 | 0.08 | 3.5 | 0.75 | 3.3 | 1000 | 67 | 12 | 210 | 11.5 | 4.1 |
| | B | 5.1 | 0.03 | 1.7 | 0.46 | 4.4 | 930 | 47 | 3 | 200 | 8.3 | 2.0 |
| Norrtälje: | | | | | | | | | | | | |
| A. hortensis | A | 4.5 | 0.12 | 5.6 | 1.20 | 0.75 | 95 | 29 | 9 | 61 | 8.7 | 5.6 |
| | B | – | – | – | – | – | – | – | – | – | 6.8 | 4.3 |
| S. oleracea | A | 3.8 | 0.02 | 8.3 | 0.82 | 0.94 | 200 | 46 | 10 | 200 | 9.9 | 7.3 |
| | B | – | – | – | – | – | – | – | – | – | 5.9 | 4.0 |

Note: Data from Carlsson and Hallqvist 1981. A. hortensis and S. oleracea grown with fertilizer at Lund (15.5 g $N/M^2$, 15 g $P_2O_5/M^2$, 30 g $K_2O/M^2$), and without fertilizer at Norrtälje. A: Fresh leaves, B: blanched leaves.

Table 2. Amino acid composition of whole leaf protein concentrate (g/16 g N). – Effects of processing conditions

| Amino acid<br>Type of protein | Lys | His | Thr | Met | Cys | Leu | Ile |
|---|---|---|---|---|---|---|---|
| Leaf protein | | | | | | | |
| No suppl./water wash | 6.4 | 2.6 | 5.4 | 2.6 | 1.1 | 9.3 | 4.5 |
| No suppl./water and ethanol wash | 6.6 | 2.6 | 5.5 | 2.6 | 1.2 | 9.3 | 5.4 |
| $SO_3^{2-}$-suppl./water wash | 7.1 | 2.6 | 5.2 | 2.8 | 1.3 | 9.6 | 5.6 |
| Comparisons | | | | | | | |
| Human reference pattern | 5.5 | – | 4.0 | 3.5 | | 7.0 | 4.0 |
| Chicken rèference pattern | 5.0 | 2.0 | 3.5 | 3.5 | | 7.0 | 4.0 |
| Rat reference pattern | 9.0 | 2.5 | 5.0 | 5.0 | | 7.0 | 5.5 |

Note: Leaf protein concentrates were performic acid oxidized, human reference (FAO/WHO 1973), chicken reference (Pommeranz 1975), rat reference (Rama rao et al. 1964), pulped plants contained 1.5 ppm $SO_3^{2-}$, no supplement means only water added during plant pulping. Data from Carlsson et al. 1975

unsaturated fatty acids, especially when the concentrate was prepared by sulphite addition during plant pulping to prevent oxidation [5]. The total fatty acids of the lipids contained 16% palmitic acid, 11% oleic acid, 28% linoleic acid and 45% linolenic acid (sulphite addition). The amino acid composition of whole leaf protein concentrate was excellent compared with FAO human reference pattern and chicken reference pattern, while rat reference pattern indicated sulphur amino acids and lysine as limiting acids (Table 2). The amino acid needs of rat thus will give an erroneous low nutritive value in *in vivo* tests (cf Table 3).

The nutritive value *in vivo* of whole protein concentrate is affected by plant material and its processing conditions [4]. Positive effects on leaf protein concentrate quality by sulphite treatment of processed plant material have been shown for different species [1, 18]. Biological value (BV), true digestibility (TD), and net protein utilization (NPU) of whole *A. hortensis* leaf protein concentrate in a rat assay was shown to be dependent on plant physiological stages at plant harvest, and on processing conditions (Table 3). Addition of reducing sulphite during plant pulping (cf above), and washing of the wet concentrate with ethanol had beneficial effects on the protein quality. Studies of protein efficiency ratio (PER) of whole *A. hortensis* leaf protein concentrate indicated positive effects of water washings of the concentrate [6]. A sulphite addition as mentioned above also increased PER from 1.5 to 2.0 [6 = casein PER: 2.5)].

Oxidative processes, e.g., causing oxidation of phenolics to quinones [15], may have reduced the availability of sulphur amino acids [5]. The positive effect of a cystine supplementation of the diet, supported that (Table 3C).

Table 3A. Nutritive value of whole leaf protein concentrate. – Effects of plant physiological development stages

| Physiological stages<br>Type of concentrate: | Vegetative | Bud setting | Flowering | Seed setting |
|---|---|---|---|---|
| Water washed | | | | |
| BV | 58 | 68 | 58 | 52 |
| TD | 82 | 87 | 87 | 84 |
| NPU | 48 | 59 | 50 | 43 |
| Water and ethanol washed | | | | |
| BV | 60 | 68 | 60 | 57 |
| TD | 93 | 93 | 90 | 85 |
| NPU | 55 | 63 | 55 | 48 |

Table 3B. Nutritive value of whole leaf protein concentrate. – Effects reducing sulphite addition during pulping

| Physiological stages | Bud setting/Flowering | Flowering/Seed setting |
|---|---|---|
| Water washed concentrate: | | |
| BV | 70 | 63 |
| TD | 92 | 92 |
| NPU | 64 | 58 |

Table 3C. Nutritive value of whole leaf protein concentrate. – Effects of a cystine addition to diet to counteract oxidative damage of sulphur amino acids during processing

| Physiological stages<br>Type of concentrate | Flowering<br>Water washed | | Seed setting<br>Sulphite added, water washed | |
|---|---|---|---|---|
| Type of diet | Control | 0.1% cys | Control | 0.1% cys |
| BV | 57 | 70 | 63 | 77 |
| TD | 90 | 88 | 92 | 93 |
| NPU | 52 | 63 | 58 | 71 |

Note: *In vivo* tests are based on 4 rats (Miller and Bender 1955). For repeated groups of four rats SD is less than ± 3% of indicated value. BV = biological value, TD = true digestibility, NPU = net protein utilization. In case of sulphite treatment the content is 4 ppm in pulped plants. Casein control: BV = 69, TD = 100, NPU = 69. Data from Carlsson et al. 1975.

The wet-fractionation of plants into a leaf protein concentrate and a pressed crop reduced the amounts of soluble secondary substances in both products compared with the original plant material [3, 6]. When the concentrate was washed with water and/or ethanol the contents of, e.g., saponins and phenolics were reduced [5, 6]. As leaf protein/nutrient concentrate contained less anti-nutritive factors than, e.g., unprocessed leaves, the concentrate may be a better product for consumption by humans than leaves of certain vegetables.

Leaf protein/nutrient concentrate is used as a pre-school children food supplement in India [12] and elsewhere in Asia.

## Conclusion

*Atriplex hortensis* L. was superior to *Spinacia oleracea* L. as a 'spinach' due to higher yields and a longer harvest season, as the quality of the leaves was similar. The leaf protein had an excellent amino acid composition for human consumption. A properly processed whole leaf protein concentrate had high nutritive *in vivo* values. Other leaf nutrients as well are concentrated together with the protein. A high proportion of the extractable leaf protein could be obtained as a white protein concentrate (85% true protein of DM). White leaf protein concentrate can be useful for food industry. Thus *A. hortensis* should be valuable both as a 'spinach', and as a source for leaf protein/nutrient concentrate.

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