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Breeding leafy vegetables for folate enrichment

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Abstract

Vitamin B9 or folate is an essential vitamin for human health, especially in developing countries where they suffered with folate deficiency. Though, the folate fills are supplied as an artificial source, biofortification is the best source for addressing the folate deficiency in human beings in future. Though, kale, broccoli, cauliflower, cabbage, parsley and beets are the available sources of folate, but spinach and lettuce are one of the identified enriched sources due to the genetic and trait diversity available to a crop underpins any attempt at genetic improvement.

1. Introduction

Folate is natural water soluble vitamin B9. It is found in plants and animal foods as well. Foliates act as co-factors in the cell cycle and crucial in the DNA biosynthesis and methylation cycle, which are vital for normal cell function. The folic acid and food folate are different structurally and in bioavailability. Folic acid is more readily absorbed. One glutamic acid is present in folic acid and 2-7 glutamic acids are present in folate (Figure 1).

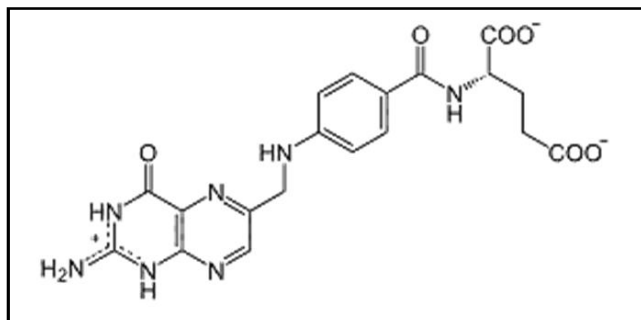


Figure 1: Folate structure.

As humans and animals unable to synthesize folates *de novo* and, hence, depends upon their dietary sources. Food folate levels vary

based on crops species. The recommended dietary allowances (RDAs) of folate is of 400 mg/day (adults) and 600 mg/day (pregnant women). Folate deficiency is a emerging health problem, and is responsible for 10% adult deaths from heart disease. Its deficiency is the main cause of anemia and leading to health problems in 10 million pregnant women in the developing world. The findings indicate to eat high folate content vegetables than the synthetic folic acid to have a higher margin of safety.

2. Leafy vegetable crops as the sources of folate

Leafy vegetables are common food items in a well-balanced diet, and increased consumption of fruit and vegetables. For folate, leafy green vegetables such as spinach beans and lettuce are the best sources. Staple crops like potato, cassava, corn and rice are poor in folate content. Two approaches, *i.e.*, pharmacological supplementation (folate pills) and biofortification of crops are used to rectify the folate deficiency.

The recent addition is folate biofortification, which is the breeding to increase folate levels in edible parts of plants. This is an economical approach to fight against folate deficiency in humans. Screening of germplasm with elevated folates are useful for both breeding and direct use. Biofortification is a feasible means of reaching malnourished populations in rural areas.

Folate levels in vegetables are relatively high. Considering their consumption, vegetables represent a rich source of folates in the human diet. Foliates contained in raw vegetables, as analysed by HPLC method, were found to range between 27 and 187 mg/100 g and between 9 and 114 mg/100 g .

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Green leafy vegetables (Table 1) rich in folate content ($\mu\text{g}/100\text{ g}$) are Kale, raw (141 $\mu\text{g}/100\text{ g}$), Collards, raw (129 $\mu\text{g}/100\text{ g}$), Broccoli, raw (63 $\mu\text{g}/100\text{ g}$), Cauliflower, green raw (57 $\mu\text{g}/100\text{ g}$), Cabbage, Savoy, raw (80 $\mu\text{g}/100\text{ g}$), Cabbage, raw (43 $\mu\text{g}/100\text{ g}$), Endive, raw (142 $\mu\text{g}/100\text{ g}$), Cabbage Chinese, raw (66 $\mu\text{g}/100\text{ g}$), Parsley, fresh (152 $\mu\text{g}/100\text{ g}$), Beets, raw (109 $\mu\text{g}/100\text{ g}$), Brussels sprout, raw (61 $\mu\text{g}/100\text{ g}$), and Spinach, raw (194 $\mu\text{g}/100\text{ g}$).

Vegetables	Folate content ($\mu\text{g}/100\text{g}$)
Broccoli, raw	63
Beets, raw	109
Brussels sprout, raw	61
Cabbage Chinese (pak-choi), raw	66
Cabbage Chinese (pe-tsai), raw	79
Cabbage, Savoy, raw	80
Caabage, raw	43
Cauliflower, green, raw	57
Endive, raw	142
Kale, raw	141
Collards, raw	129
Parsley, fresh	152
Spinach, raw	194
Peas edible podded, raw	42
Peas, green, raw	65
Soybean, green, raw	165
Cowpea (black eyes), immature seeds, raw	168
Beans Fava, pods, raw	148

Table 1: Folate content in various green leafy vegetables.

2.1 Spinach

It is an important leafy vegetable, considered to have a high nutritional value, including antioxidants, vitamins, minerals and secondary metabolites. Spinach (Figure 2) has enormous genetic diversity, among which might be high-folate germplasm. It might be worth identifying the spinach germplasm with elevated amounts of folate, could be used as a variety without any modification or as a source of genes to introgress into crop species. It contains high amount of folate.



Figure 2: Spinach leaves.

The folate content in 67 spinach accessions collected from the United States Department of Agriculture and Asian Vegetable Research and Development Center (AVRDC) revealed that the total folate content ranged from 54.1 to 173.2 $\text{mg}/100\text{ g}$ of fresh weight, with 3.2-fold variation. Four accessions, *i.e.*, PI 499372, NSL 6095, PI 261787, and TOT7337-B have enriched folate content. The large variation of folate content in accessions indicated the genetic potential of diverse genotypes to be used by plant breeders.

2.2 Lettuce

Folate content expressed in folic acid equivalents, in the lettuce samples varied six-fold, from 30 to 198 $\mu\text{g}/100\text{ g}$ on a fresh weight basis (Johansson *et al.*, 2007). A group of researchers from the Brazilian Agricultural Research Corporation (EMBRAPA) and the University of Brasilia developed several lettuce lines accumulating high levels of folate. The lettuce plants (Figure 3) express a synthetic *gchI* gene, based on a native chicken gene, which encodes an enzyme that plays a central role in the folate biosynthetic pathway. The GM lettuce lines contain 2-8 times higher folate levels than the non-transgenic lines. According to the researchers, the folate content in enriched lettuce would provide 26% of the dietary reference intake (DRI) for an adult, in a regular serving (Nunes *et al.*, 2009).



Figure 3: Lettuce plant.

3. Folate retention during boiling

The folate retention during boiling under constant conditions differs between the individual vegetables. The highest retention values were found in Brussels sprouts, cauliflower, and broccoli. After 8 min boiling, more than 75% of the initial 5-MTHF content was retained. Lower values of retention between 37% and 52% of the initial 5-MTHF content, were measured in spinach, savoy cabbage, and carrot. The differences in the folate retention between respective vegetables might be related to the vegetable properties such as the weight/surface ratio or the presence of endogenous antioxidants.

4. Conclusion

Folate (vitamin B9) is essential in the human diet, deficiency leads to malnutrition and inadequate folate intake leads to several serious health concerns. Most of the staple food crops are poor sources of dietary folates. Leafy vegetables are the good dietary source of folates. Spinach is one the sources of elevated folate for human diet besides kale, broccoli, cauliflower, cabbage, parsley, beets and spinach. Biofortification will be a cheapest sources for enriching the

crops with folate levels and correcting the folate deficiency in human beings in future.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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