HortScience 14(1):48–49. 1979.

Fruit Concentrations of Amino Acids in Several Strawberry Cultivars in Relation to the Time of Harvest[1]

J. F. Gallander
Department of Horticulture, Ohio Agricultural Research and Development Center, Wooster, OH 44691

Additional index words. Fragaria sp., mature fruit, asparagine

Abstract. **Fully mature fruit from 4 cultivars of strawberry (*Fragaria* X *ananassa* Duch.) were examined for free amino acids at 3 harvest times. Aspartic acid, asparagine, glutamic acid, and glutamine accounted for 79 to 87% of the total free amino acids in these cultivars. Asparagine, the most prominent amino acid, decreased from early- to late-harvest.**

Information is limited on the amino acid composition of strawberries, especially as influenced by cultivar. Most findings have been obtained from general survey studies (1, 4, 5, 7). In general, the major amino acids in strawberries are reported to be alanine, asparagine, glutamic acid, aspartic acid, and glutamine. These investigators also reported the absence of proline in strawberries. However, according to Fernandez-Flores et al. (2), proline was found in 6 strawberry samples at levels of 1.5 mg/100 g or less. The major component was aspartic acid with moderate amounts of alanine, aminobutyric acid, and glutamic acid. Recently, Temperli and Kunsch (6) found that 4 strawberry cultivars contained large amounts of glutamine and asparagine; 40 to 69% of the total amino acid content. They also reported the tendency of amides and acidic amino acids to decrease during maturation. The present study was initiated to determine the effect of cultivar and harvest time on the amino acid composition of mature strawberries.

Ripe fruit, 2 kg each, of 'Robinson', 'Raritan', 'Guardian', and 'Midway' strawberries was harvested 3 times (early, middle, and late) during the 1973 season. All cultivars were grown in Ohio under standard production practices at the same location. Duplicate samples (1 kg) of each cultivar and harvest were selected for amino acid determinations. Fruits without caps were sliced in half and pressed through cheesecloth. The juice was frozen, thawed and centrifuged to give a clear sample. Amino acid analyses were performed after centrifugation and precipitation of the protein using sulfosalycilic acid (0.1 ml of 50% solution per ml of juice). Norleucine was added as an internal standard, and the amino acids were determined with a Technicon amino acid analyzer.

The cultivars were qualitatively similar in amino acid composition (Table 1). These results were in general agreement with most of the previous studies (1, 2, 4, 5, 6, 7). Although the absence of proline was observed in this study, Fernandez-Flores (2) reported a range of proline content in strawberries up to 1.5 mg/100 g.

Asparagine was the most prominent amino acid (38-50% of the total) (Table 1). This preponderance of asparagine in the fruits was observed during the entire fruiting season. Other amino acids present in relatively large amounts were: aspartic acid, glutamine, and glutamic acid. These 4 amino acids accounted for 79 to 87% of the total free amino acids in the various cultivars. Other amino acids in strawberries included moderate amounts of threonine, serine, glycine, and alanine.

The most striking observation in this study was the decrease in asparagine in fully mature fruit as the harvest season progressed. This was especially true for 'Robinson', in which the asparagine content was reduced from 218 to 75 mg/100 ml in early- and late-harvested fruits, respectively. However, comparison of asparagine concentration in all cultivars indicated that the greatest decrease occurred during the first half of the harvest season. This also coincided with the rapid reduction in total free amino acids. It appears that early maturing fruit accumulate large amounts of nitrogenous compounds, principally asparagine. This is just before harvest when the supply of photosynthates is highest, a time the strawberry plant is fully developed and essentially in a non-growing condition. Extensive runner development may begin late in the harvest season, and may have an important influence on the amount of amino acids being translocated to the fruit. It is possible that the increased demand for asparagine in actively growing parts, such as stolons, may explain the low level of this metabolite in middle- and late-harvested fruit. The preferential decrease of asparagine during the harvest season suggests that the strawberry has a special requirement for this amino acid. The amide has been shown to be a major component of the soluble amino nitrogen in apple trees (3, 8). The importance of asparagine is related to its ease of translocation and metabolism. The possibility exists that measuring the level of asparagine may be used to accurately estimate the nitrogen needs of the strawberry plant.

[1]Received for publication June 30, 1978. Approved for publication as Journal Article No. 99-78 of the Ohio Agricultural Research and Development Center, Wooster, Ohio 44691.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

Table 1. Concentration of amino acids in fully mature fruit of 4 strawberry cultivars at different harvest times.

Amino acid	Amino acid concn (mg/100 ml of juice)[z]											
	Robinson			Midway			Guardian			Raritan		
	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Aspartic acid	23	13	18	26	19	21	19	11	14	22	18	20
Threonine	7	6	5	9	6	6	4	4	3	7	5	6
Serine	12	6	16	11	8	14	7	5	7	9	16	11
Asparagine	218	105	75	183	121	102	136	64	60	201	150	136
Glutamic acid	33	20	34	33	31	44	21	21	28	25	22	34
Glutamine	47	24	34	49	33	32	36	25	27	39	36	36
Glycine	5	3	3	4	4	5	4	5	5	5	4	4
Alanine	15	9	13	14	10	13	10	9	8	18	14	16
Total	370	193	205	342	242	251	244	153	160	338	212	271

[z]Valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, and arginine ranged from trace to 4 mg/100 ml of juice in all cultivars; proline was not detected in any cultivar.

Literature Cited

1. Burroughs, L. F. 1960. The free amino acids of certain British fruits. *J. Sci. Food Agric.* 11:14-18.
2. Fernandez-Flores, E., D. A. Kline, A. R. Johnson, and B. L. Leber. 1970. Quantitative and qualitative GLC analysis of free amino acids in fruits and fruit juices. *J. Assoc. Off. Agr. Chem.* 53:1203-1208.
3. Hill-Cottingham, D. G., and D. R. Cooper. 1970. Effect of time of application of fertilizer nitrogen on nitrogenous constituents of apple trees. *J. Sci. Food Agric.* 21:172-177.
4. Rockland, L. B. 1959. Free amino acids in citrus and other fruit and vegetable juices. *J. Food Sci.* 24:160-164.
5. Silber, R. L., M. Becker, M. Cooper, P. Evans, P. Fehder, R. Gray, P. Gresham, J. Rechsteiner, and M. A. Searles. 1960. Paper chromatographic identification and estimation of the free amino acids in thirty-two fruits. *J. Food Sci.* 25:675-680.
6. Temperli, A. and U. Künsch. 1976. Der gehalt an freien aminosäuren in unreifen und reifen erdbeeren. *Gartenbauwissenshaften* 41:123-125.
7. Tinsley, I. J., and A. H. Bockian. 1959. Chromatographic identification and estimation of the free amino acids present in strawberry juice. *J. Food Sci.* 24:410-412.
8. Tromp, J., and J. C. Ovaa. 1971. Spring mobilization of storage nitrogen in isolated shoot sections of apple. *Physiol. Plant* 25:16-22.

HortScience 14(1):49–50. 1979.

Effects of Glyphosate on Highbush Blueberry (*Vaccinium corymbosum* L.)[1]

Laurie Hodges, R. E. Talbert, and J. N. Moore[2]
Univesrsity of Arkansas, Fayetteville AR 72701

Additional index words. Vaccinium sp., weed control

Abstract. **Five-year-old 'Collins' highbush blueberries were treated in August with glyphosate (*N*-phosphonomethyl glycine) at 0.36, 3.6 and 7.2 g/liter acid equivalent as a spot treatment alone or with pruning or applying paraquat (1, 1'-dimethyl-4, 4'-bipyridinium ion) at 1.2 g/liter to remove green tissue prior to glyphosate application. Initial response was terminal dieback of young canes. Symptoms the following spring included additional terminal dieback, leaf and cane morphological aberrations, and elongation of the flower corolla. One year after treatment, regrowth was normal. There was no effect on blueberry yield the season following treatment.**

Glyphosate has potential for use as a postemergence systemic herbicide against weeds such as bermudagrass [*Cynodon dactylon* (L.) Pers.] and johnsongrass [*Sorghum halepense* (L.) Pers.] in perennial fruit crops. Its properties and mode of action have been described by Baird et al. (1) and Jaworski (3), respectively. Glyphosate metabolism and degradation in soil and water were described by Rueppel et al. (6). Rom and Talbert (4) and Rom et al. (5) suggested that rates sufficient for controlling weeds in apple and peach orchards were phytotoxic to foliage and green bark of young trees. Abnormal leaf development and inhibition of leaf and flower formation were observed when the glyphosate was applied the previous autumn before leaves were shed. Tucker (7) also reported morphological aberrations on citrus plants as a result of using glyphosate, but he found the herbicide to be effective in the control of weeds. We evaluated glyphosate to determine its phytotoxic effect on highbush blueberries.

The test was conducted at the Main Experiment Station, University of Arkansas at Fayetteville on a Captina silt loam soil with 1% organic matter and 10% clay. The 1% Roundup[3] solution (containing 3.6 g/liter acid equivalent to glyphosate plus surfactant) was the standard rate used (2). Each treatment consisted of one 5-year-old plant per replication. The experimental design was a randomized complete block design with four replications. Plots were kept weed-free by hand hoeing.

Paraquat and glyphosate treatments were applied August 12 and 19, 1976 respectively, with a hand sprayer to the point of spray runoff. Treatments included: a) a control; b) paraquat alone at 1.2 g/liter (0.5% solution) applied to the lower one-third of the plant; c) glyphosate at 0.36 g/liter (0.1% solution) applied to all leaves and canes to simulate a drift rate; d) glyphosate at 3.6 g/liter (1% solution) applied to the lower one-third of the plant; e) glyphosate at 7.2 g/liter (2% solution) applied to the lower one-third of the plant; f) paraquat at 1.2 g/liter (0.5% solution) applied to the lower one-third of the plant to remove green tissue, followed 1 week later by glyphosate at 3.6 g/liter applied to the lower one-third of the plant; and g) pruning of all leaves and green canes from the lower one-third of the plant 1 week prior to application of glyphosate at 3.6 g/liter applied to the lower one-third of the plant. Percent injury was determined by visual ratings based on plant vigor, growth abnormalities, chlorosis, and necrosis. A scale of 0 (no injury) to 100 (total kill) was used. Plants were not pruned in the winter of 1976.

Three weeks after the August treatment, all glyphosate-treated plants exhibited some terminal dieback, but injury was greatest where green tissue was exposed to either 3.6 or 7.2 g/liter (Table 1).

The next spring, injury symptoms included small, strap-shaped leaves with some chlorosis, elongated flower corolla, delay in flowering, additional terminal dieback of canes, dead canes, and proliferation of latteral shoots to form "witches brooms." Although younger, more succulent growth showed the most injury, old wood was also damaged, especially where glyphosate was applied

Table 1. Effect of glyphosate applied in August on mature highbush blueberries.

Treatment	Rate (g/liter)	Injury (%) 3 weeks after treatment (Sept. 1976)	Injury (%) At bloom (April 1977)	Injury (%) 1 yr. after treatment (Sept. 1977)	Yield 1977 (kg/plant)	Avg wt (g/25 berries)	Avg growth (cm) (Sept. 1976–Sept. 1977)	New canes/plant (Sept. 1976–Sept. 1977)
Check	– –	0	9	4	2.1	33.4	18	6
Paraquat	1.2	2	12	6	1.8	33.7	30	4
Glyphosate	0.36	22	17	23	2.6	34.5	22	2
Glyphosate	3.6	28	24	20	2.7	33.9	21	1
Glyphosate	7.2	44	40	46	2.4	32.8	22	0
Paraquat & glyphosate	1.2 & 3.6	19	16	14	2.8	34.0	36	3
Pruning & glyphosate	3.6	6	19	13	2.7	31.6	26	5
	$LSD_{5\%}$	20	NS	19	NS	NS	NS	NS

[1]Received for publication September 9, 1978. Published with the approval of the Director, Arkansas Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2]Research Assistant and Professor, Agronomy Dept., and Professor, Horticulture Dept., respectively.

[3]Trade names are used in this publication solely for the purpose of providing specific information and do not suggest endorsement of the product.