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Received for review April 1, 1976. Accepted September 7, 1976. This project was financed by the U.K. Meat and Livestock Commission and the University of London Central Research Fund.

Comparison of Nutrient Composition and of Enzyme Activity in Purple, Green, and White Eggplants

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Tissues of purple, green, and white varieties of eggplant, *Solanum melongena*, grown under identical conditions in the same area, were analyzed for percent moisture and total solids. The total solids were further analyzed for crude protein, amino acid composition, ether-extractable lipids, crude fiber, ash, and nitrogen-free extract. Trace elements in the dried matter were determined by neutron activation analysis. Activities of three enzymes (polyphenol oxidase, alcohol dehydrogenase, and catalase) were compared in the three varieties. Composition of the total solids and activities of these enzymes in the three varieties are discussed with respect to their effects on keeping quality of fresh or processed eggplants. Based upon these data, the green variety appears to have better properties for processing than the more popular purple variety.

The growing interest in nutrient composition of foods can be attributed in part to the new FDA nutritional labeling regulations. In the past there was little concern for variations in nutrient contents of many established vegetables because the development of new varieties emphasized higher yields or better processing and storage characteristics, rather than nutrient composition. Recent research on the requirements of several essential trace elements has stimulated investigations on the sources and availabilities of these minerals in plant foods (Leveille et al., 1974).

To ensure a year-round supply of fresh and processed fruits and vegetables we need a better understanding of the initial composition and of certain enzymes that catalyze biochemical changes in fresh vegetables during extended storage, or before and during processing. Adverse changes due to overripening or deterioration of the tissue can lower final quality of the product.

Eggplants are grown only to a limited extent in northern climates because they need a long, warm, frost-free growing season of 14 to 16 weeks for good yields (Combs et al., 1973). Although the purple fruit is the most widely used, other varieties are known that differ in size, shape, and color. A white variety has been grown in Europe for many years, but apparently for ornamental purposes only (Dumonthay, 1936). A round, light green eggplant has been grown in India (Viraktamath et al., 1963) and is currently appearing in home gardens in the southern United States, but it has not been found to a significant degree in fresh produce markets. A pink and a black eggplant has been cultivated in India (Singh et al., 1974), but their acceptance has been based only on external characteristics such as color, shape, and size of the fruit.

Polyphenol oxidase (EC 1.10.3.1) is probably a major cause of discoloration in eggplants that have been subjected to rough handling, storage, peeling, and processing. This enzyme utilizes the tannins and phenolic compounds in the tissue as substrates, causing brown products. Lipoxygenase (EC 1.13.1.13), which can also produce off-flavors from polyunsaturated fatty acids, was found in purple eggplants by Pinsky et al. (1971). The first comparison of lipoxygenase activity and its inhibition by KCN in purple, green, and white eggplants was recently reported (Flick et al., 1975). Two other enzymes in fresh vegetables which may be related to keeping quality are catalase (EC 1.11.1.6), which catalyzes decomposition of the hydrogen peroxide that is toxic to plant cells, and alcohol dehydrogenase (ADH) (EC 1.1.1.1), which converts the resulting aldehyde products of lipoxygenase activity to alcohols in tea seeds (Hatanaka and Harada, 1972). These studies were undertaken to compare the nutrient composition and three enzymes that can affect flavor and quality of purple eggplants with the two lesser known green and white varieties.

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MATERIALS AND METHODS

Since many factors (i.e., soil conditions, irrigation, fertilization, growing areas, and maturity at harvest) can influence the levels of specific nutrients or components in the fruits or seeds of plants, all three color varieties of eggplants were grown in adjacent rows in the same outdoor plot under identical conditions in Chalmette, La., and harvested at approximate stages of maturity. Buffer salts and normal reagents were purchased commercially. Enzymes used as standards (polyphenol oxidase, catalase, and alcohol dehydrogenase) were purchased from Worthington Biochemical Corp. Mature fruits of each color variety were peeled and a flesh portion removed. Care was exercised to prevent seeds from being included with the sample. An aliquot of cold (3 °C) deionized water was added to the excised flesh and the mixture was homogenized at high speed for 3 min. The homogenate was freeze-dried in a Virtis freeze-dryer.

Nitrogen contents were determined by the Kjeldahl method. Total solids, moisture, crude protein, crude fiber, ether extracts, nitrogen-free extract, and ash were analyzed by the AOAC method (1970).

The freeze-dried materials were ground in a blender, mixed, and subsampled for analysis. About 1 g of each sample was weighed into a clear polyethylene vial (1.5 cm i.d. × 2 cm high) and analyzed for a range of elements by nondestructive neutron activation. The samples were irradiated twice; once for a short period which varied depending on sodium and chlorine contents but was on the order of 1 min and again for approximately 4 h. The neutron flux to which the samples were exposed was about 10^{12} for the long irradiation. After the short irradiations, the samples were counted within a few minutes on a Ge(Li) counting system for 8 min. An Intertechnique SA-44 4000 channel analyzer was used and the data stored on magnetic tape for later processing. For long irradiations, the samples were counted as soon as practicable considering the level of activity due to sodium. The time interval varied from 2 to 5 days after irradiation. The samples were recounted later after a minimum of 10 days decay.

Freeze-dried tissues of the eggplants were analyzed on a Beckman autoanalyzer using recommended procedures in the Beckman Manual (Beckman Instruments, 1972), according to the methods described by Spackman et al. (1958). The freeze-dried tissue was hydrolyzed 24 h with constant-boiling hydrochloric acid in a nitrogen atmosphere inside a sealed tube.

Polyphenol oxidase, catalase, and alcohol dehydrogenase activities were assayed by the methods described in the Worthington Enzyme Manual (1972). Extracts for each assay were freshly prepared by homogenizing 15 g of small pieces of fresh tissue (about 1 cm^3) in 60 ml of deionized water for 30–60 s at 0 °C in a food blender, rapidly pouring the mixture into a fluted filter paper, and immediately filtering the first 25–30 ml of filtrate coming in through sintered glass by mild vacuum. The clear extracts were placed in a crushed ice bath and assayed within 2 to 3 min.

RESULTS AND DISCUSSION

Eggplants are generally picked before the seeds proliferate and the flesh becomes tough. Excessive delay in getting fresh produce from field to storage, to processors, or to market can result in changes and loss of nutrients. Damage from handling also activates enzymes that affect quality because enzymes are primarily responsible for most changes in quality of fresh tissue. Figure 1 shows the three varieties of eggplants picked at the same stage of maturity. The purple eggplant is the more pear-shaped of the three, the green and white varieties having a more rounded shape.

Composition of Eggplants. Information on the basic composition and properties of vegetables can be utilized in selecting the varieties that are best for storage in fresh produce markets, or for improving storage methods. The final conditions for storing various types of produce, however, depend upon factors such as growing conditions, keeping quality of the variety, and harvesting and handling practices.

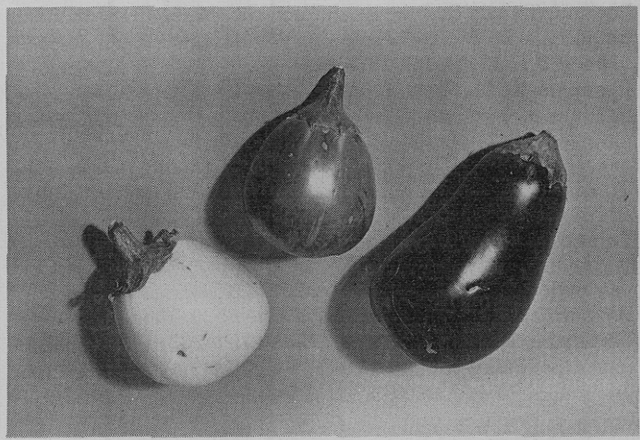

Figure 1. Purple, green, and white eggplants (right to left) picked at the same stage of growth.

Table I. Composition of Three Types of Eggplants

(A)

Analysis	Solids and moisture content, % Purple	Green	White
Solids	6.4	5.8	7.8
Moisture	93.6	94.2	92.2

(B)

Substance	Compn of solids, % of total, dry wt basis Purple	Green	White
Nitrogen	2.02	2.04	1.78
Ether extract	0.88	0.81	0.79
Crude fiber	10.85	11.93	22.32
Ash	4.56	8.57	7.37

(C)

Element	Elem. compn, ppm, dry wt basis[a] Purple	Green	White
Al	123.0	76.9	132.5
Br	2.66	2.66	6.55
Ca	1 450	1 090	1 068
Cd	0.2	0.5	0.2
Cl	2 060	3 590	2 785
Co	0.37	0.61	0.67
Cr	3.4	2.4	2.5
Cu	21.8	13.2	14.6
F	49.5		
Fe	164	180	157
K	17 390	28 220	27 475
Mg	1 690	1 245	1 280
Mn	11.7	14.8	10.0
Mo	0.59	0.50	0.65
Na	306	211	232
Rb	40.2	9.2	11.9
S	3 800		9 950
Se	2.0	1.1	1.5
Sn	4.4	5.0	9.5
Zn	6.1	8.0	5.8

[a] By neutron activation analysis.

Table I lists the composition of each of the three varieties. The high content of water in all three is typical of fleshy vegetables, as is the low protein content. White eggplants contained the greatest amount of solids, whereas the green contained the lowest. There was a variation in percent solids among the three varieties with the white variety containing 34% more solids than the green.

The ether-extractable lipids are quite low. Crude protein was higher in the purple and green eggplants than the

Table II. Amino Acid Profiles of Proteins in Eggplants (Dry Weight Basis)

	Content, mg/g		
Amino acid	Purple	Green	White
Lysine	0.769	0.541	0.541
Histidine	0.475	0.338	0.332
Ammonia	0.558	0.744	0.401
Arginine	1.206	0.724	1.033
Aspartic acid	3.274	2.666	1.969
Threonine	0.776	0.527	0.493
Serine	0.815	0.568	0.562
Glutamic acid	3.582	2.992	2.405
Proline	0.784	0.585	0.534
Glycine	0.776	0.542	0.548
Alanine	0.995	0.658	0.677
Half-cystine[a]			
Valine	1.212	0.807	0.795
Methionine[b]			
Isoleucine	0.722	0.655	0.638
Leucine	1.266	0.950	0.944
Tyrosine	0.419	0.287	0.313
Phenylalanine	0.869	0.617	0.617

[a] Measured as cysteic acid. [b] Measured as methionine sulfone.

white. Both the green and white varieties contained more ash than the purple.

Crude fiber was similar in both the purple and green varieties, while the white variety contained almost twice as much. A report by Sherman (1974) indicates that there is a negative correlation between incidence of heart disease and dietary fiber. The white variety would be a more nutritionally important source of fiber in the diet.

The purple variety contained the highest percent nitrogen-free extract; the green was intermediate and the white was lowest.

Mineral composition of freeze-dried fruit was determined by neutron activation analysis, a method sensitive enough for both qualitative and quantitative analyses (Table I, part C). All three varieties have high concentrations of potassium, chlorine, magnesium, and calcium. Potassium and chlorine are highest in the green and lowest in the purple variety, whereas the reverse is true for magnesium and calcium. Purple eggplants contained 49.5 ppm of fluorine but none was detected in the white and green varieties. Most mineral contents for the white variety appear to lie somewhere between those found in the other two varieties. A number of other elements were found but in less than the reliable limits of detection by this method. It is worth noting that all three varieties are low in sodium, an advantage for people on low sodium diets.

The amino acid profiles in Table II are typical of those for plant protein. The green and the white eggplants contain similar amounts of 12 amino acids. The white was higher in arginine, whereas the green was higher in both aspartic and glutamic acids. The amounts of all amino acids were higher in the purple eggplants than in either the white or the green varieties. Cystine and methionine were not detected. The amino acid levels of the white variety are too low to be nutritionally important but the purple eggplant may have nutritional value in countries where total protein is limited.

Enzyme Activities. Polyphenol oxidase activities are shown in Figure 2. Activity was highest in the purple variety, decreased in the green, and was lowest in the white. Both catalase (Figure 3) and alcohol dehydrogenase (ADH) activities (Figure 4) were highest in the green variety and slightly less in the purple; the white had only one-third of the activities found in the green. Nevertheless, de-

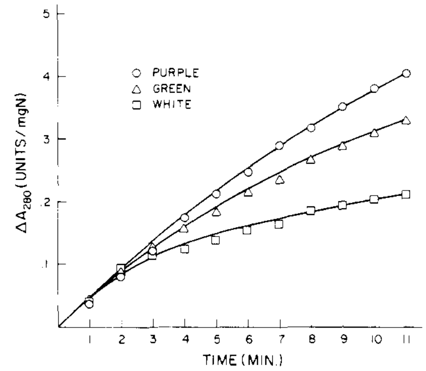

Figure 2. Polyphenol oxidase activity in purple, green, and white eggplants. Conditions described under Materials and Methods, pH 6.5 buffer and 0.5 ml of enzyme extract in test samples; enzyme in the controls.

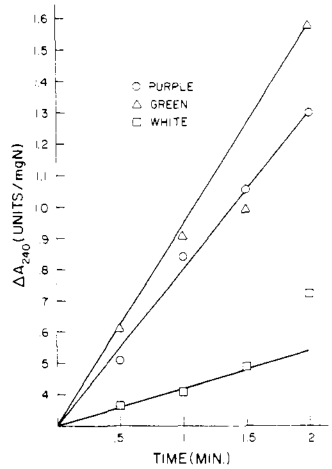

Figure 3. Catalase activity in purple, green, and white eggplants. Conditions: similar to those in Figure 2 except that pH was 7.0 and 0.6 ml of enzyme extract was used in test solutions; none in the controls.

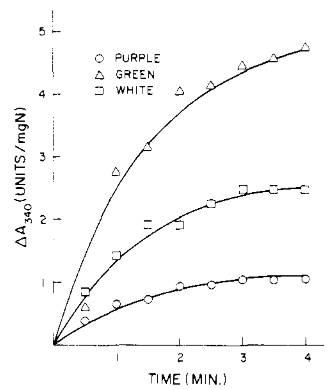

Figure 4. Alcohol dehydrogenase activity in purple, green, and white eggplants. Conditions described under Materials and Methods; pH 8.0, 0.3 ml of enzyme extract used in test samples; none in the controls.

composition of hydrogen peroxide was quite rapid, and the best activity curves were obtained with only 0.2 ml of eggplant extract (50 mg of fresh tissue). ADH activities were low in all three varieties, but highest in the green.

The highest polyphenol oxidase activity in the purple variety seemed most evident during peeling. Darkening of the peeled fruit when exposed to air appeared to occur faster in the purple variety. This was observed by Constantin et al. (1974), who reported that green eggplant cultivators discolored less than the purple-pigmented ones.

Some of these oxidized phenolic products (dark pigments) may contribute bitter flavors to cooked eggplant products. There is no evidence for the induction of off-flavors in vegetables by in vivo accumulation of hydrogen peroxide, but since excessive H_2O_2 can be toxic to plant cells, its removal by catalase could be beneficial. Although ADH was reported to catalyze the conversion of hexenol to hexanal in tea seeds (Hatanaka and Harada, 1972), hexanal was produced from linoleic acid by peanut lipoxygenase (St. Angelo et al., 1972). The low ADH activity found in all three varieties makes it difficult to classify this enzyme as a significant cause of off-flavors in eggplants.

If the copper, iron, and zinc contents in Table I are compared to the relative enzyme activities in the corresponding varieties (Figures 2, 3, and 4), an interesting observation is noted. All three are metalloenzymes, polyphenol oxidase (Cu), catalase (Fe), and ADH (Zn). There appears to be a correlation between the amount of copper present and the polyphenol oxidase activity (purple, green, and white, in decreasing order); also between the amounts of iron in each variety and the catalase activities (green, purple, and white, in decreasing order). Both the zinc content and ADH activity are highest in the green variety, but enzyme activity is slightly higher in the white than in the purple, whose zinc contents are 5.8 and 6.1 ppm, respectively.

Although polyphenol oxidase is not the only copper enzyme present (no measurements were made for ascorbic acid oxidase), and catalase is certainly not the only iron-containing hemoprotein in plants (cytochromes and peroxidase also contribute to this value), there was a correlation between metal content and activity in seven of the nine samples compared. The relative amounts of polyphenol oxidase and catalase activities in the purple and green varieties may help to explain why the green variety is considered to have a milder flavor than the purple (unpublished information). One grower stated that he grew purple eggplants for fresh produce markets and the green variety for his own consumption because of the better flavor.

The results of these studies on three varieties of eggplants indicate that characterization of keeping quality of fresh fruits and vegetables should include a study of the biochemical properties of the species and the variety. Such studies, including both chemical analyses of the different varieties and the relative amounts of selected enzymes that affect organoleptic properties, can provide useful information for processors and for fresh produce markets.

ACKNOWLEDGMENT

Appreciation is expressed to SRRC for the use of their facilities to conduct part of this research, to J. J. Bergquist (SRRC) for the photography, and to A. K. Furr, VPI & SU Neutron Activation Analysis Laboratory, for analysis of the trace elements.

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Received for review June 10, 1976. Accepted August 31, 1976. Mention of companies or products does not imply recommendation by the U.S. Department of Agriculture over others not mentioned.