

MASSACHUSETTS AGRICULTURAL  
EXPERIMENT STATION.

APPLES AS FOOD.

BY

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and Marie S. Gutowska.

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## Apples as Food

By William B. Esselen, Jr., Carl R. Fellers,

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Apples owe their widespread popularity to their attractiveness and palatability. Now with recognized food values assigned to them, apples also assume importance as a "protective food" in the American diet. This bulletin summarizes information on composition and nutritive value.

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# APPLES AS FOOD<sup>1</sup>

By William B. Esselen, Jr., Associate Research Professor of Food Technology, Carl R. Fellers, Head of the Department, and Marie S. Gutowska, Assistant Research Professor

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## INTRODUCTION

Since ancient times special curative powers have been attributed to the apple. We are all familiar with a modification of the old Devonshire rhyme (Manville, 1936a)—

“Ate an apfel avore gwain to bed,  
Make the doctor beg his bread.”

Apples have been widely used as a food from the earliest times and they hold a place of well-deserved popularity today. According to Todhunter (1937) there are many reasons why this fruit has received dietary recognition.

It has “color appeal”: green, red, russet or yellow, it catches the eye; it has “appetite appeal”: cool, crisp, and raw it is most refreshing; and the thrifty like it because it has “variety appeal.” No other fruit can be used in so many different ways. Raw or cooked, made into preserves and jellies, candied, dried, canned, prepared as fresh apple juice, made into cider or vinegar, and the peelings used for pectin making, no part of the apple need be wasted.

During the past ten years considerable effort has been expended in an attempt to make the public nutrition or vitamin conscious. Through scientific research the nutritive qualities of many foods have been evaluated and the results of such investigations have been applied to the improvement of the human diet. As an outgrowth of this development the nutritive value of a food has been used as a strong sales argument for its greater use in many cases. We hear such stories every day on the radio and read them in the newspapers and magazines. In spite of all this publicity, appetite appeal is still all-important to the individual in his choice of foods, and he is reluctant to choose a food on its nutritional merits alone if it lacks eye appeal and appetite appeal.

Apples have won their enviable position through their aesthetic and appetite appeal, but research has shown that they also possess definite nutritional and therapeutic properties.

This bulletin summarizes the results of eighteen years of research on the nutritive and therapeutic values of apples as carried on in this department, as well as the wealth of information reported by other investigators. Much interest has been shown in Massachusetts regarding the nutritive value of apples; both by the fruit grower and by the consumer. This interest has gone so far that some people even appear to prefer to think of apples as a bottle of vitamin pills rather than as an attractive and flavorful fruit. However, in all probability, apples will continue to maintain their popularity on a basis of their flavorful and refreshing characteristics, with their nutritive value secondary in importance.

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<sup>1</sup> Acknowledgment is due to the Massachusetts Society for Promoting Agriculture for their interest and assistance in the preparation of this bulletin.

### HISTORY OF THE APPLE

The apple has been grown in Europe for more than two thousand years. The cultivated apple, *Malus Sylvestris* (*M. communis*), probably had its origin in mountain ranges of the Caucasus, between the Black and Caspian Seas. The wild forebears of the apple are also found in adjoining regions of Asia Minor and Persia (Varilow, 1930).

It is believed that the name "apple" originated in Abella, a town in Campania, where many fruit trees grow, and that Virgil conferred it upon a number of fruits to which the gardener gives the name apple; namely, the balsam apple, the rose apple, the pineapple, and the love apple (tomato) (King, 1946).

The apple was brought to North America by the earliest settlers, and was rapidly disseminated from coast to coast throughout the temperate zone of the United States (Magness, 1941). After 1800 when grafting became more generally known and practiced, the number of named varieties increased rapidly (Gourley and Howlett, 1941). For convenience of discussion, Shaw (1911) divided North America into seven apple belts, each having a fairly characteristic list of varieties. In the apple trade, however, apples are classed mainly as "Western" and "Eastern." The leading Western varieties are Winesap, Jonathan, Delicious, Yellow Newtown, Rome Beauty, and of the early apples—the Gravenstein (United States Department of Agriculture, 1935).

In New England no less than fifty varieties can be found in commercial orchards. Of these, McIntosh and Baldwin are the only two of real importance, and the latter is declining. Northern Spy, Rhode Island Greening, Cortland, Wealthy, and Delicious are among the more important minor varieties.

### APPLE PRODUCTION AND CONSUMPTION

The total world's crop of apples exceeds 500 million bushels. This figure is based on reports from thirty-one countries for a six-year period (1931-36), and allowance is also made for the crops in such important countries as the U.S.S.R. and China, for which definite information is lacking (Gourley and Howlett, 1941).

However, with the greatly increased supplies of other fruits, apple consumption in the United States has apparently decreased during the past thirty years, and consequently, the number of apple trees has also decreased.

Figure 1 shows the per capita civilian consumption of apples in the United States for the period of 1909-43 (United States Department of Agriculture, 1944). Whereas the per capita consumption of apples decreased from approximately 60-70 pounds to 40-60 pounds from 1909 to 1920, it has declined from 62 to 36 pounds during the period 1920 to 1930, and from 51 to 25 pounds during the period 1930 to 1943.

Figure 2 shows the total United States production of apples from 1909 to 1938 and Figure 3 the number of trees and the average yield per tree from 1909 to 1934 (United States Department of Agriculture, 1938). Whereas the decrease in the number of trees of bearing age is about 45 percent; the yield per tree, owing to improved methods of culture, has increased about 70 percent.

There has been a rather steady decrease in the per capita consumption of apples from 1910 to date. Some persons have attributed this decrease to the increased availability of other fruits, particularly grapefruit and oranges. The substitution of these other fruits can probably be attributed to the desire for variety as well as other factors such as advertising and developments in the field

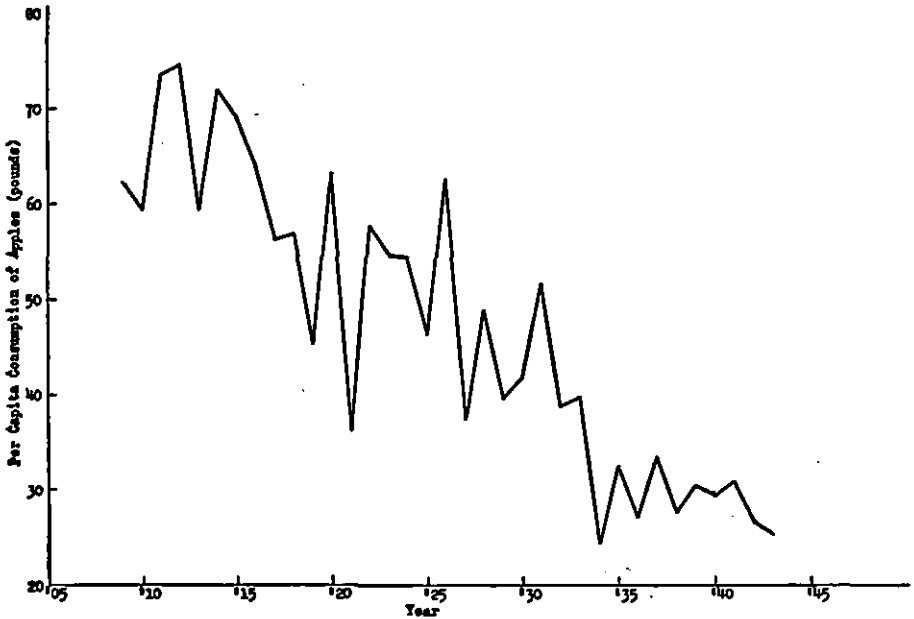


Figure 1. Per Capita Consumption of Apples in the United States, 1909-1943.  
(United States Department of Agriculture, 1944.)

of nutrition. The spectacular increase in the production of canned fruit juices since about 1930 may well have played a part in the decreased consumption of apples. During the past few years there has been a definite trend indicating that people prefer many fruits in a form that they can drink.

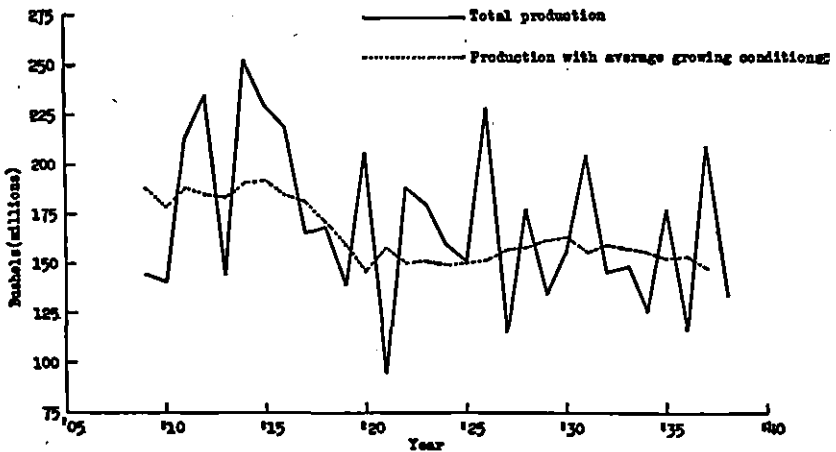


Figure 2. Apples: Total United States Production and Production with Average Growing Conditions, 1909-1937.  
(United States Department of Agriculture, 1938.)

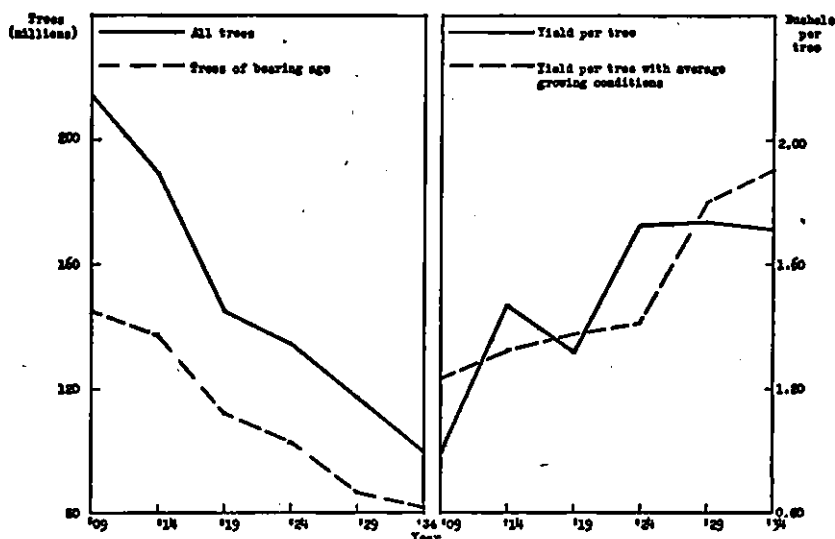


Figure 3. Apples: Number of Trees and Average Yield per Tree, 1909-1943. (United States Department of Agriculture, 1938.)

THE COMPOSITION OF APPLES

In a consideration of the nutritive value of a foodstuff its chemical composition is of primary importance. Information on the average chemical composition of the edible portion of fresh apples is presented in Table 1. Additional data on the composition of different varieties of Massachusetts-grown apples, as determined by Fellers (1928) and Holland and Ritchie (1941), are shown in Tables 2 and 3.

TABLE 1.—AVERAGE CHEMICAL COMPOSITION OF THE EDIBLE PORTION OF FRESH APPLES (Chatfield and Adams, 1940)

Constituent	All	Early (summer)	Medium (fall)	Late (winter)
	percent	percent	percent	percent
Water.....	84.1	86.5	85.4	83.6
Protein.....	0.3	0.3	0.3	0.3
Fat.....	0.4	0.4	0.3	0.3
Ash.....	0.29	0.3	0.25	0.28
Carbohydrate (total).....	14.9	12.5	13.8	15.5
Fiber.....	1.0	—	1.1	—
Sugars.....	11.1	9.4	10.4	11.2
Starch.....	—	—	—	—
Acid (as malic acid).....	0.47	0.70	0.45	0.46
Fuel or energy value (In Calories)				
Per 100 grams.....	64.0	55.0	59.0	66.0
Per pound.....	290.0	250.0	270.0	300.0

TABLE 2.—CHEMICAL COMPOSITION OF CERTAIN VARIETIES OF MASSACHUSETTS APPLES  
(Fellers, 1928)

Variety	Year	Number of Samples	Total Solids	Soluble Solids	Total Sugars	Reducing Sugars	Sucrose	Starch	Pectin as Pectic Acid	pH	Acidity as Malic	Ash
			percent	percent	percent	percent	percent	percent	percent		percent	percent
Baldwin.....	1925	3	18.06	15.50	11.72	7.12	4.60	0.08	0.29	3.55	0.45	0.27
Baldwin.....	1926	2	16.79	14.12	9.93	6.22	3.71	trace	0.32	3.42	0.61	0.29
Baldwin.....	1927	2	15.90	13.60	11.01	7.58	3.43	0.11	0.37	3.47	0.53	0.33
Red Astrachan.....	1926	1	15.31	12.61	9.20	5.99	3.21	0.18	0.28	3.18	1.11	0.35
Rhode Island Greening..	1926	2	15.70	12.91	10.00	7.80	3.20	0.10	0.34	3.37	0.51	0.31
Winesap.....	1926	2	18.61	15.79	13.52	10.03	3.49	trace	0.31	3.45	0.47	0.32
McIntosh.....	1926	3	15.70	13.28	12.09	9.13	2.96	0.0	0.27	3.60	0.38	0.28
Wealthy.....	1926	1	13.83	11.76	10.60	8.90	1.70	0.0	0.30	3.40	0.47	0.26
King David.....	1926	1	14.98	12.28	10.60	8.68	1.92	trace	0.47	3.25	0.91	0.28
Red Siberian Crab.....	1926	2	16.17	12.76	10.25	8.47	1.78	0.09	0.62	3.20	0.80	0.36

TABLE 3.—COMPOSITION OF APPLES  
(Holland and Ritchie, 1941)

Variety	Original Moisture	Crude Protein*	Crude Fat*	Nitrogen Free Extract*	Crude Fiber*	Crude Ash*		Iron*	Copper*	Man- ganese*	Calcium*	Phos- phorus*
						Soluble	Insoluble					
	percent	percent	percent	percent	percent	percent	percent	p.p.m.	p.p.m.	p.p.m.	percent	p.p.m.
Baldwin, cored.....	85.0	1.60	1.62	89.46	5.62	1.70	0.00	35	12	none	0.024	790
McIntosh, cored.....	86.4	1.34	1.96	90.68	4.89	1.12	0.01	11	2	trace	0.043	510
Wealthy, cored and pared..	87.4	0.98	2.00	90.55	4.61	1.84	0.02	54	9	none	—	630
Baldwin, cored and pared..	85.7	1.11	0.73	92.78	4.05	1.32	0.01	21	5	trace	—	770
McIntosh, cored and pared	85.4	1.27	0.86	93.09	3.61	1.15	0.02	34	5	trace	—	690
Baldwin, skins.....	80.7	2.42	4.81	82.50	8.35	1.90	0.02	39	5	14	—	770
McIntosh, skins.....	81.8	1.65	4.81	85.79	6.70	1.03	0.02	30	11	trace	—	640

\*Dry weight basis

There is some variation in the composition of apples according to variety and other factors. Ordinarily more than four-fifths (80 to 86 percent) of the apple consists of water. The total solids vary from approximately 14 to 19 percent, of which 12 to 15.5 percent is soluble solids. Sugars make up a large proportion of the solids (approximately 75 percent and approximately 12 percent of the total weight of the apple). The chief organic acid of the apple is malic acid, which is found to the extent of from 0.5 to 1.0 percent. Citric acid has been found in only a few varieties.

### Carbohydrates

From a nutritional standpoint carbohydrates can be divided into two groups: the so-called available carbohydrates such as starches and sugars; and the unavailable or fiber fraction consisting of pectin, cellulose, and hemicellulose, usually considered indigestible.

The young apple contains a relatively large amount of starch (3 to 4 percent), but as the fruit ripens the starch is converted into sugars. A fully ripe apple contains little or no starch.

The total available sugar content of the apple amounts to approximately 12 percent. The sugars consist of at least three distinct compounds; sucrose (from 0 to 6 percent), and a mixture of dextrose and levulose of which there may be from 5 to 10 percent. The excess of levulose over dextrose is rather unusual in fruits (Shaw, 1911). According to Manville (1936b) the excess of levulose in apples may account for the greater tolerance of diabetics for this fruit.

According to Sherman (1946) one good-sized apple will furnish 100 calories, which is equivalent to the energy provided by one fair-sized potato, one thick or two thin slices of bread, or two-thirds of a glass of milk (about five ounces). Apples may be considered a food of moderate energy value, comparing favorably in this respect with many of the other fruits such as apricots, blueberries, oranges, peaches, pears, plums, raspberries, and strawberries.

The caloric value of the apple is relatively well utilized in the body according to Ullmann (1933), who found that 88.3 percent of the caloric value of ingested apples was assimilated by the body.

### Pectin

As a nutritive element in apples, pectin is particularly interesting. Pectin was discovered in 1825 by Braconnot, a French scientist, who first suggested that this material might be of value as an antidote for lead poisoning (Rooker, 1928). However, pectin was only a laboratory curiosity until 1909, nearly 100 years later. At that time investigators established the relationship between pectin, sugar, and acid. In 1913 the first patent for the commercial production of pectin was issued to Douglas. Since that time it has come into general use in jelly and preserve making.

The pectin content of fresh apples averages about 0.5 percent. Chemically, pectin is a polygalacturonate, containing 8 molecules of galacturonic acid. It was pointed out by Manville (1936b) that galacturonic acid plays a definite role in mucin formation and in this respect has a vitamin A-sparing action.

The uronic acid content of apples, as reported by Manville (1936b) and shown in Table 4, appears to vary with the variety of apple; but in all cases apples were considerably richer in this compound than such fruits as lemons, oranges, or tomatoes.



TABLE 4.—URONIC ACID VALUE OF SOME APPLE VARIETIES AND OTHER FRUITS  
(Manville, 1936b)

Variety	Uronic Acid per Gram of Fruit
	milligrams
Arkansas Black.....	10.6
Baldwin.....	9.8
Delicious.....	11.8
Gravenstein.....	7.3
Jonathan.....	8.5
Rome Beauty.....	13.3
Spitzenberg.....	12.1
Winesap.....	13.9
Winesap juice.....	5.4
Yellow Newtown.....	16.5
Lemon juice filtered.....	2.0
Orange juice filtered.....	4.0
Tomato juice filtered.....	2.0

Kobren, Fellers, and Esselen (1939) investigated the effect of adding pectin to the diet of vitamin A-deficient rats in order to observe its vitamin A-sparing action. It is generally recognized that xerophthalmia and the keratinization of the mucous epithelium of the body are due in part to a deficient synthesis of mucin, occurring as a result of dehydration of the mucous membranes. From this investigation, pectin appeared to be a beneficial supplement to a diet deficient in vitamin A only insofar as pathological changes due to avitaminosis A in the vagina, nares, and eyelids are concerned.

The effectiveness of raw apples in the treatment of diarrhea is attributed largely to their pectin content, as will be discussed more fully later.

### Minerals

The apple contains approximately 0.25 to 0.36 percent of ash. The approximate composition of the ash of the edible portion of the apple as compared with other fruits is shown in Table 5. Although apples cannot be considered an important source of minerals, they are comparable to other fruits in this respect, and their liberal use in the diet does contribute definite amounts of these specific nutrients.

The iron, phosphorus, and calcium in the apple have been reported to be highly available and fully utilized by the human body. Moreover, the preponderance of base-forming elements makes the apple an efficient agent in reducing the acid output. The principal base-forming elements in apples are potassium, sodium, calcium, and magnesium, of which potassium occurs in the greatest quantity.

In addition, it is of interest to note that apples contain traces of iodine.<sup>2</sup> The

<sup>2</sup> The estimated daily requirement of humans for iodine is about 0.002 to 0.004 milligram a day for each kilogram of body weight. This amounts to about 0.15 to 0.30 milligram daily for the adult. Iodine is especially important in adolescence and pregnancy. (U.S. National Research Council, 1945.)

TABLE 5.—PERCENTAGES OF CERTAIN OF THE MINERAL ELEMENTS IN THE EDIBLE PORTION OF FRUITS  
(Sherman, 1946)

Kind of Fruit	Calcium	Magnesium	Potassium	Sodium	Phosphorus	Chlorine	Sulfur	Iron	Copper	Manganese
	percent	percent	percent	percent	percent	percent	percent	percent	p.p.m.	p.p.m.
Apples.....	.007	.006	.116	.010	.011	.004	.005	.0003	.71	.84
Apricots, fresh.....	.015	.009	.279	.030	.024	.002	.006	.0005	*	*
Blackberries.....	.032	.024	.181	.004	.032	.015	.017	.0009	*	*
Blueberries.....	.026	.010	.065	.016	.020	.008	.011	.0009	*	*
Orange (or juice).....	.025	.010	.181	.010	.019	.004	.008	.0003	.76	.25
Peaches.....	.009	.011	.256	.015	.018	.005	.007	.0003	*	*
Pears.....	.013	.009	.129	.008	.016	.004	.007	.0003	1.34	.64
Pineapple, fresh.....	.016	.011	.214	.014	.011	.046	.007	.0003	*	*
Plums.....	.017	.011	.232	.004	.020	.002	.005	.0005	.80	.96
Raspberries, seed included	.040	.023	.190	.003	.037	.022	.018	.0009	*	*
Rhubarb.....	.051	.016	.358	.017	.025	.053	.008	.0005	*	*
Strawberries.....	.022	.012	.145	.007	.022	.011	.012	.0009	.75	2.13

\*No figure available

iodine content of apples and applesauce has been determined by Nebraska and Ohio investigators, who found that dried Nebraska apples contain from 89 to 340 parts per billion of iodine. Dried apples in the Oregon goitrous region contained only 3 parts per billion; whereas Ohio applesauce showed 125 parts per billion of iodine (American Can Company.)

### Acids

The chief organic acid of the apple is malic acid, which is found to the extent of from 0.5 to 1.0 percent. Citric acid has been found in only a few varieties. Crab apples may contain as much as 0.03 percent citric acid, Yellow Transparent 0.02 percent, and Winesap a trace. Apples also contain a small quantity of tannic acid (which contributes astringency to their flavor) and uronic acid. Uronic acid is closely related to pectin, as discussed previously. Ursolic acid, a complex organic acid, is one of the principal components of the waxy coating of the skin of the apple.

Apples as eaten have an acid reaction, but because of their buffering capacity they influence the acid-base balance of the body as an alkaline food. The organic acids of the apple are oxidized in the body to furnish energy and leave a basic residue in the blood. The preponderance of base-forming elements in the apple leads to the formation of a urine less acid than normal. The apple thus safeguards the body from reduction of the bicarbonate concentration or alkali reserve of the blood.

One of the first studies of the titrable acidity and hydrogen-ion concentration of New England apples was made by Fellers (1928), who found that the acidity of Massachusetts varieties of apples varied only in very narrow limits, namely from pH 3.6 to pH 3.2. The relation between total titratable acidity and hydrogen-ion concentration was reasonably constant; i.e., the higher the hydrogen-ion concentration the higher the acidity and vice versa. Some varieties appeared to contain more buffer substances than others. The titratable acidity of apple juice and jelly manufactured from these apples was also determined. The juice was slightly lower in hydrogen-ion concentration than the fruit itself; the second and third extracts were lower than the first. The total acidity of the finished jelly, calculated as malic acid, varied from 0.22 percent in McIntosh to 0.66 percent in Red Siberian Crab; while the pH value ranged from 3.2 in Red Astrachan to 3.6 in Baldwin.

The hydrogen-ion concentration and the titratable acidity of thirteen varieties of New York apples was determined by Pfund (1939). Nearly all had pH values between 3.0 and 4.0; and if all the titratable acid is considered to be malic, the molarity values are between 0.070 M and 0.013 M. Of all the apple fruits examined, approximately 86 percent had pH values between 3.1 and 3.7 and molarity values between 0.055 M and 0.18 M. The differences between the pH values of raw apple juice, baked apples, and applesauce were not significant; therefore, the pH value of the raw apple juice may be considered as representative for the acidity of the cooked product. The data are shown in Table 6.

The basic effect of apples on the alkali reserve of the blood and acidity of the urine was studied by Shea and Fellers (1942). The term "alkali reserve" refers to the amount of basic elements (such as calcium, magnesium, potassium, and sodium) combined as bicarbonates in the blood. These bicarbonates provide a readily available source of base for the neutralization of acids. Nine healthy men from 22 to 27 years of age were placed on two diets; one group received an acid-

TABLE 6.—ACIDITY AND PH VALUES OF THIRTEEN VARIETIES OF APPLES GROWN IN NEW YORK STATE (based on 302 samples, 1930 to 1935) (Pfund, 1939)

Variety	Average Acidity* and pH Values					
	October to January		February to April		October to April	
	Acidity*	pH	Acidity*	pH	Acidity*	pH
Baldwin.....	10.7	3.26	6.4	3.45	8.6	3.35
Cortland.....	7.0	3.33	5.1	3.56	6.6	3.46
Fameuse.....	6.1	3.38	4.6	3.56	5.6	3.45
Golden Delicious.....	7.0	3.44	3.7	3.83	5.0	3.67
Jonathan.....	9.0	3.29	6.6	3.45	7.8	3.37
McIntosh.....	6.5	3.31	4.5	3.56	5.6	3.42
Northern Spy.....	9.6	3.21	6.9	3.34	8.6	3.25
Red Canada.....	8.0	3.38	4.2	3.60	6.3	3.47
Rhode Island Greening.....	9.4	3.25	8.1	3.38	8.9	3.30
Rome Beauty.....	5.1	3.32	4.2	3.50	4.7	3.40
Twenty Ounce.....	8.6	3.22	5.3	3.45	7.6	3.29
Wealthy.....	7.6	3.20	6.6	3.32	7.2	3.26
Winter Banana.....	5.7	3.41	4.2	3.55	5.1	3.47
All Varieties.....	7.7	3.31	5.4	3.50	6.7	3.39

\* Average milliliters of N/10 NaOH required to neutralize 10 milliliters of raw juice.

forming basal diet and the other an approximately neutral basal diet. The neutral diet was chosen because the effect of added apples on urinary acidity could not be foreseen. The acid-forming basal diet was used because it was believed that if the ingested material increased the alkalinity of the urine, the results would be more evident. Baldwin and McIntosh apples were tested. Large quantities (800 and 1000 grams) of these were eaten daily by the men on the experiment. The alkali reserve was expressed as cubic centimeters of carbon dioxide per 100 cubic centimeters of blood plasma. The data are summarized in Table 7.

The ingestion of large quantities of Baldwin or McIntosh apples caused a slight reduction in the pH value of the urine but did not significantly affect the blood alkali reserve; also approximately 90 percent of the organic acids of apples was completely oxidized or otherwise transformed in the body on either acid-forming or neutral diets.

The fact that there was no significant increase in urinary acidity in human subjects as a result of eating large quantities of apples indicates the probable absence of benzoic and quinic acid in apples.

The European worker, Marynowska-Kaulbersz (1933); reported that an apple diet tended slightly toward alkalosis.

It may be of interest that Fellers, Redmon and Parrott (1932) investigated the effect of cranberries on urinary acidity and blood alkali reserve, and found that when eaten in normal quantities (2 to 5 ounces of cranberry sauce, equivalent to 22 to 54 grams of fresh cranberries) no demonstrable effect on blood alkali reserve could be observed. However, when large quantities of cranberries were eaten (100 to 300 grams) a mild to moderate acidosis resulted.

TABLE 7.—SUMMARY OF AVERAGED DATA ON pH, ORGANIC ACIDITY AND AMMONIA OF URINE AND PLASMA ALKALI RESERVE  
(Shea and Fellers, 1942)

Diet	Subject*	pH		Organic Acidity		Ammonia		Alkali Reserve		Days Run (Urine sample taken daily)
		Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	Acid Diet	Neutral Diet	
		pH		c.c. of 0.1 N acid		grams		cc. of CO <sub>2</sub> /100 cc. of plasma		
Basal.....	G & F	5.55	6.10	619	355	.430	.376	61	65	4
Basal.....	G & F**	5.52	6.36	569	379	.420	.281	64	70	4
McIntosh Apples, 800 grams.....	R & S	5.55	6.00	571	441	.380	.342	62	65	4
McIntosh Apples, 800 grams.....	R & S	5.40	5.89	608	437	.540	.327	63	58	4
Basal.....	D & C	5.77	6.00	355	351	.358	.284	64	67	4
Basal.....	D & C	6.04	6.29	330	308	.535	.322	65	68	4
Baldwin Apples, 1,000 grams.....	J & K	5.72	5.50	422	482	.505	.410	63	63.5	2
Baldwin Apples, 1,000 grams.....	J & K	5.50	5.70	433	350	.680	.346	61	63.5	2
Basal.....	D & C	5.81	5.98	577	489	.494	.308	61	65	4
Basal.....	D & C	5.92	6.13	608	518	.624	.398	60	66	4
Tomatoes, 1,000 grams.....	L & K	6.02	5.87	569	430	.474	.295	62	65.5	2
Tomatoes, 1,000 grams.....	L & K	5.95	6.07	735	591	.520	.566	60	63.5	2
Basal.....	D & C	5.75	6.05	537	552	.569	.279	60	64	4
Basal.....	D & C	5.75	6.12	688	609	.578	.414	60	60	4
Dates, 400 grams.....	L & K	5.63	6.22	730	625	.538	.278	60	65	2
Dates, 400 grams.....	L & K	5.44	5.96	709	591	.523	.378	61	61	2

\*Subjects G, R, D, J, and L were on the acid-forming diet; subjects F, S, C, and K were on the neutral diet.

\*\*The subjects were allowed two days on the basal diet in the first two experiments with apples before any urine samples were taken.

### Protein

The apple contains a somewhat smaller percentage of protein than many of the other fruits. The proximate composition of the apple shows 0.3 percent of protein as compared with 0.6 percent in blueberries, 0.6 percent in cantaloupes, 0.5 percent in watermelon, 0.4 percent in pineapple (Sherman, 1946).

The few available studies on the amino-acids of the protein of apples indicate that it is composed mainly of arginine, histidine, and lysine, all of which belong to the group of "essential amino-acids," indispensable in mammalian nutrition. The proportion of the amino-acids remains fairly constant during the development of the apple. The amide nitrogen forms 24.8 percent, the amino-nitrogen 45.3 percent; the "rest" nitrogen, including imino-nitrogen, 20 percent; nitrogen formed from  $\text{NH}_3$  6.3 percent; and basic nitrogen 3.6 percent (Hulme, 1936). Research on the nature of the protein of the apple is now in progress in this department.

### Flavor

Shaw (1911) stated that the characteristic flavor and aroma of apples is due to certain esters or flavoring oils which are of great importance in determining the quality and value of the apple. Power and Chestnut (1920) analyzed the odorous constituents of several varieties of apples and found them to consist essentially of the amyl esters, acetic and caproic acids, with a very small amount of caprylate and a considerable portion of acetaldehyde. The essential oil possessed to a high degree the characteristic fragrant odor of fresh apples. The yield of oil from the peel of Ben Davis apples was 0.0035 percent and from that of crab apples 0.0043 percent, corresponding to about 0.0007 and 0.0013 percent, respectively, of the entire ripe fruit. In an examination of McIntosh apples, Power and Chestnut (1922) confirmed the results of their earlier investigations that the odorous constituents of the apple consist chiefly of amyl esters, and obtained further information respecting the substance that imparts a distinctly roselike odor to some apples. This substance, present in minute amounts, was found to be geraniol.

More recently Milleville and Eskew (1944) have described a commercial method for the recovery and utilization of natural apple flavors. The product is a colorless water solution of the volatile constituents of natural apple flavor concentrated from 100 to 150 fold. The actual proportion of flavoring constituents in the solution does not exceed a few tenths of one percent by weight. The odor of the concentrate was mildly pungent and no perceptible changes have been found to occur in the product during storage.

### Oils and Waxes

Oils and waxes exist in the apple, particularly in the peel, in very small quantities. Sando (1923) investigated the constituents of the waxlike coating on the peel of the apple and isolated triacontane ( $\text{C}_{30}\text{H}_{62}$ ), heptacosanol ( $\text{C}_{27}\text{H}_{56}\text{O}$ ), and an alcohol, malol ( $\text{C}_{30}\text{H}_{48}\text{O}_2$ ), as well as several other fractions apparently consisting of mixtures of hydrocarbons and alcohols. In further work Markley and Sando (1931) found that ursolic acid (a monohydroxytriterpene acid), oil fraction, and total ether extract in the peel of apples increased throughout the growing period and during storage. Larger quantities of ursolic acid and total

ether extract were generally found on the shady side of apples than on the sunny side.

Chibnall et al. (1931), in a study of the wax constituents of the apple cuticle, identified nonacosane, heptacosane, d-10-nonacosanol, hexacosanol, octacosanol and triacontanol. Hulme (1937) determined the wax content of apples during different stages of storage and found that the fraction soluble in cold alcohol and the ether-soluble fraction increased during storage from 139.4 milligrams per 100 grams of fresh tissue to 175.5 milligrams. The fraction insoluble in alcohol but soluble in ether increased from 14.5 to 36.1 milligrams per 100 grams of fresh tissue.

### Vitamins<sup>3</sup>

Apples have been found to contain at least small amounts of most of the known vitamins. The average vitamin values based on available information are summarized in Table 8. These data are only approximate because the vitamin content is subject to considerable variation depending upon the variety and other factors which will be discussed later.

TABLE 8.—AVERAGE VITAMIN CONTENT OF APPLES PER 100 GRAMS EDIBLE PORTION

Vitamin A.....	50-100 International Units....
<b>B Vitamins</b>	
Thiamin.....	.096 milligrams
Riboflavin.....	.05 milligrams
Nicotinic Acid.....	.50 milligrams
Pantothenic Acid.....	.030 milligrams
Pyridoxin.....	.026 milligrams
Biotin.....	.0009 milligrams
Inositol.....	24.0 milligrams
Folic Acid.....	.008 milligrams
Ascorbic Acid (Vitamin C).....	1.0-20.0* milligrams
Vitamin D.....	none

\* Varies greatly with variety and storage conditions. An average value for common varieties may be taken as 2.0 to 5.0 milligrams.

<sup>3</sup> The recommended daily allowance for the vitamins considered here is as follows\*:

	Vitamin A	B Vitamins			Vitamin C
	I. U.	Thiamin Mg.	Riboflavin Mg.	Niacin, Mg. (Nicotinic Acid)	(Ascorbic Acid) Mg.
Men.....	5,000	1.2-2.0	1.6-2.6	12-20	75
Women.....	5,000	1.1-2.0	0.5-2.0	11-20	70-150
Pregnant.....	6,000				
Lactating.....	8,000				
Children (depending on age).....	1,500-6,000	0.4-1.8	0.6-2.5	4-18	30-100

\*U. S. National Research Council, 1945.

TABLE 9.—VITAMIN CONTENT OF APPLES AS COMPARED WITH OTHER FRUITS  
(per 100 grams)  
(Sherman, 1946)

Kind of Fruit	Vitamin A	Ascorbic Acid	Thiamin	Riboflavin
	I. U.	milligrams	micrograms	micrograms
Apples.....	40 - 100	4.0 - 8.0	21 - 46	5 - 26
Oranges (or juice).....	50 - 400	50.0 - 56.0	66 - 96	15 - 90
Peaches, yellow (fresh).....	1,000 - 2,000	6.0 - 9.0	20 - 70	45 - 50
Pears.....	10 - 20	3.0 - 5.0	30 - 95	20 - 150
Pineapple (fresh).....	40 - 60	13.0 - 25.0	80 - 125	20 - 80
Plums.....	350	4.0 - 7.0	48 - 200	30 - 44
Raspberries.....	320	8.0 - 75.0	20 - 30	70
Rhubarb.....	30 - 100	9.0 - 24.0	10 - 25	—
Strawberries.....	60 - 90	49 - 60	30	30 - 70

Table 9 shows an evaluation of the apple as a vitamin carrier in comparison with some other fruits. Apples do not rank high as vitamin carriers. In this respect, they are similar in value to pears, plums, and rhubarb. However, the nutritional value of the apple would be greatly misrepresented if it were considered only as a source of vitamins.

### Vitamin A

Potter (1933) found practically no difference in the vitamin A content of three varieties (McIntosh, Red Delicious, and Golden Delicious) of apples grown in Washington. The presence of yellow pigment in the apple was not related to vitamin A potency. Potter showed that apples are equal to orange juice in vitamin A content and that they compare favorably with other fruits as a source of vitamin A. Fraps and Treichler (1933) indicate that apples are rather an expensive source of vitamins as compared with many other foods.

Vitamin A occurs in apples and in all plants only as carotene. There is some question as to the equivalent potencies of vitamin A and carotene. Recent research seems to show equal or nearly equal potencies, although the usual conversion factor is 1.0 International Unit of vitamin A = 0.66 micrograms of carotene.

In compilation of data on the vitamin content of foods, Daniel and Munsell (1937) indicated that fresh apples contained from 58 to 147 I.U. of vitamin A per 100 grams. Todhunter (1937) reported that the peel of Richared apples was at least five times as rich in vitamin A as the flesh of the apple. Delicious apples contained approximately 102 I.U. per 100 grams of apple.

### Thiamin

The thiamin content of apples is low, and they cannot be considered an important source of this vitamin. Lane, Johnson and Williams (1942) in a study of sources of thiamin in the American diet, used apples which contained .019 milligrams per 100 grams. When apples were made into applesauce, approximately 30 percent of the thiamin was destroyed during heating. Cheldelin and Williams (1942) analyzed apples that contained 0.096 milligrams of thiamin per 100 grams. In a compilation of information on the vitamin content of foods, American Can Company (1943) indicated that apples contained from 0.010 to 0.69 milligrams of thiamin per 100 grams. The thiamin content varied with the variety.



### Other "B-Vitamins"

As may be seen in Table 8 apples contain only relatively small amounts of most of the "B-vitamins." Lanford, Finkelstein and Sherman (1941) found that the citrus fruits, bananas, and tomatoes were richer in riboflavin than the pome fruits as represented by apples and pears. Apples contained 4.3 micrograms of riboflavin per 100 grams. According to American Can Co. (1943) the riboflavin content of apples may range from 0.010 to 0.073 milligrams per 100 grams.

Tepley, Strong and Elvehjem (1942) reported that peeled apples contained 0.50 milligrams of niacin (nicotinic acid) per 100 grams and that the peel contained 1.13 milligrams. McVicar and Berryman (1942) reported similar figures.

According to Jukes (1941) apples are a poor source of pantothenic acid, containing less than .03 milligrams per 100 grams on a fresh basis. Likewise, apples are a poor source of pyridoxine according to Schneider, Ascham, Platz and Steenbock (1939).

In studies on the B-vitamin content of foods Cheldelin and Williams (1942) reported the following amounts in terms of milligrams per 100 grams of fresh apple: thiamin, 0.096; riboflavin, 0.018; nicotinic acid, 0.081; pantothenic acid, 0.060; pyridoxine, 0.026; biotin, 0.0009; inositol, 24.0; and folic acid, 0.008.

### Ascorbic Acid

Considerable work has been reported concerning the ascorbic acid content of apples and factors influencing it. One of the first studies on the ascorbic acid content of different varieties of apples grown in the United States was reported by Fellers, Cleveland and Clague (1933) and Smith and Fellers (1934). These workers investigated 21 varieties of Massachusetts-grown apples, which were classified as to their vitamin C potency as follows:

<i>Very Good</i>	<i>Good</i>	<i>Fair</i>	<i>Poor</i>
Baldwin	Esopus (Spitzenberg)	Arkansas	Jonathan
Northern Spy	Rome Beauty	Gravenstein	Delicious
Ben Davis	Red Astrachan	Wealthy	Tolman
Winesap	King	Cortland	McIntosh
	Roxbury Russet	King David	
	Rhode Island Greening	Golden Delicious	
	Stayman		

In a more recent investigation Fellers and Dunker (1940) evaluated 69 varieties of Massachusetts apples as to their ascorbic acid content, which was found to range from 0.7 to 11.6 milligrams per 100 grams of fresh fruit as shown in Table 10. Other workers have found that the ascorbic acid content of apples ranged from 1.0 to 20.8 milligrams per 100 grams.

Fellers, Isham, and Smith (1932) reported that the epidermis of Baldwin apples contains about four times as much vitamin C as the flesh immediately beneath it, and six to ten times as much as the flesh near the core. McIntosh apples also contain much more vitamin C in the peel than in the flesh.

### FACTORS AFFECTING COMPOSITION OF APPLES

As is the case with other agricultural crops, there are a number of factors that may exert an influence on the composition of apples. Because of the extensive

TABLE 10.—THE ASCORBIC ACID<sup>1</sup> CONTENT IN SIXTY-NINE VARIETIES OF APPLES GROWN IN MASSACHUSETTS. (Original data\*)

Variety	Ascorbic Acid (Fresh Basis)		Variety	Ascorbic Acid (Fresh Basis)	
	Bioassay Results	Dye Titration		Bioassay Results	Dye Titration
	mg. per 100 gm.			mg. per 100 gm.	
Arkansas.....	4.7	2.1	Montreal.....	—	1.3
Arkansas Black.....	—	2.9	Mother.....	—	1.9
Baldwin.....	12.5	5.8	Newell.....	—	5.0
Bailey Sweet.....	—	2.4	Northern Spy.....	10.0	7.5
Ben Davis.....	8.3	—	Northwestern Greening.....	—	4.5
Bietigheimer.....	—	0.9	Patricia.....	—	1.7
Bismark.....	—	1.9	Pedro.....	—	2.6
Blenheim.....	—	3.8	Pewaukee.....	—	2.1
Brock.....	—	1.2	Porter.....	—	1.4
Canada Baldwin.....	—	4.1	Pumpkin Sweet.....	—	1.3
Carlton.....	—	1.4	Ranier.....	—	3.8
Coopers' Early Seedling.....	—	1.2	Rambo.....	—	2.7
Cortland.....	4.2	3.7	Red Astrachan.....	6.2	—
Delicious.....	2.0	4.9	Red Sauce.....	—	2.5
Esopus Spitzenberg.....	—	6.0	Rhode Island Greening.....	5.8	2.3
Fall Pippin.....	—	0.7	Ribston.....	—	4.0
Fameuse.....	—	2.1	Rome Beauty.....	6.6	—
Gano.....	—	2.4	Roxbury Russet.....	5.8	—
Golden Delicious.....	3.3	1.7	Stark.....	—	3.6
Gravenstein.....	4.5	1.2	Starking.....	—	4.6
Grimes Golden.....	—	1.2	Stayman.....	5.8	—
Helm.....	—	1.2	Stimson.....	—	4.0
Hurlburt.....	—	3.1	Summer Extra.....	—	0.9
Jonathan.....	3.1	3.3	Tolman.....	2.5	—
Joyce.....	—	2.6	Tolman Sweet.....	—	2.9
King.....	5.8	3.9	Tompkins King.....	—	3.4
King David.....	3.3	7.4	Twenty Ounce.....	—	7.8
Lawver.....	—	11.6	Wagener.....	—	4.8
Limberturg.....	—	3.5	Washington Red Gravenstein.....	—	1.5
MacMahon.....	—	1.8	Wealthy.....	4.2	3.2
Maiden Blush.....	—	1.3	Winesap.....	7.7	6.6
Mann.....	—	3.8	Winter Banana.....	—	4.6
McIntosh.....	2.0	3.1	Winter St. Lawrence.....	—	2.6
Milton.....	—	3.2	Wolf River.....	—	0.8
			Yellow Belleflower.....	—	3.8

\* Dr. C. F. Dunker carried out the dye titrations for ascorbic acid.

amount of work that has been reported on the subject it is impossible to review all of it here. The present discussion will be confined to pointing out some of the factors concerned and their effect on apples.

Variety

There is evidence that each variety of apples has a characteristic chemical composition that is fairly constant when maturity is attained. Shaw (1911) stated that many of the differences found in various samples of a single variety could be attributed to a difference in the stage of maturity. Chatfield and Adams (1940) summarized data on the composition of summer, fall, and winter apples as shown in Table 1. According to this information the early varieties tend to contain slightly more water than the later varieties. The protein, fat, and ash content were fairly constant. The total carbohydrate content was slightly higher in the later varieties, whereas the acidity was highest in the early varieties.

Smith and Fellers (1934), Manville, McMinis and Chuinard (1936), Todhunter (1939), and others have discussed the differences in vitamin A, B, and C content in different varieties of apples. Some investigators have indicated that the vitamin C content of apples tends to increase as the chromosome number in the cells of vegetative tissues increases, but Smith and Fellers (1934) did not observe any such correlation.

#### Environment and Climate

Besides genetic factors the composition of the apple may also be significantly influenced by environmental factors. The effect of climatic conditions on the composition of apples has been studied extensively by Shaw (1911) and Caldwell (1928a, 1928b). According to Caldwell it would appear that the annual crop of fruit upon a perennial plant is an integrated expression of the climatic factors for the season in which it is produced in the same degree to which the growth of an annual plant is integrated with these factors. He further indicated that the mean summer temperature as a separate factor has little influence in determining the composition of apples.

Murneck (1945) compared the composition of apples during development to harvesting maturity on the outside portion of the tree with better exposure to light, and that of apples developed on shaded branches. The apples on branches with better light were almost invariably higher in ascorbic acid content than those grown on shaded branches. This was not merely "skin-deep," but extended within the flesh of the fruit. The smaller apples were somewhat higher in ascorbic acid than the larger ones. Moreover, if a limb carried a relatively light crop, the vitamin content of the apple was apt to be somewhat higher than where the yield was heavy. It was also reported that the ascorbic acid concentration in fruit borne on weak trees, was higher than in fruit on trees of high vegetative vigor. The ratio of the leaf area to fruit in relation to the vitamin C content of Delicious and Winesap apples was studied by Batchelder and Overholser (1936). The Winesap seemed to show higher vitamin C values when the ratio was low, but the Delicious apples showed no differences. The leaf-fruit ratio seemed not to affect the vitamin C content directly.

#### Soil and Fertilizer Treatment

Wilder (1909) of Massachusetts Experiment Station determined the soil adaptations of various varieties of apple trees and indicated that different varieties have decided preferences as to soil. However, Shaw (1911) states that "not enough is known regarding this question to make any very definite generalization on the subject."

The effect of fertilizers was investigated by Aldrich (1931), who applied sodium nitrate (Chili saltpeter) during the months of August and September and then studied the quality of the apple fruit. This treatment decreased the color, increased the nitrogen content and had no measurable effect on keeping quality.

Magness and Overley (1930) studied the keeping quality of apples from untreated and from nitrate- or potash-treated trees, but found no significant differences.

Todhunter (1937) reported results of studies of apples from unfertilized, normally fertilized, and heavily fertilized soil. No differences were found, either in the vitamin C content or in the nitrogen content of the apples. In general the beneficial effect of sunlight on color and flavor is well known. The quality and

size of fruit is improved by good pruning and soil fertility practices. Good moisture conditions are also required.

After reviewing the "spray residue" problem, Clague and Fellers (1936) stated that "arsenic and lead residues often persist on apples after picking. Only a small part of these toxic substances is removed by ordinary fruit washing methods. Commercially, apples are often washed in solutions containing from 0.5 to 1 percent hydrochloric acid. This treatment is effective in residue removal." In the East the normal rainfall removes most of the spray before harvest. Furthermore, orchardists are refraining from using lead or arsenic sprays during the latter part of the season. It is not believed that spray residue on apples constitutes a health hazard in the non-irrigated sections of the United States.

### Water Supply

The dessert and keeping qualities of the apple are not adversely affected when the moisture supply varies enough to permit it to fall temporarily to the wilting point, according to Gourley and Howlett (1941). They point out, however, that extremes of moisture are undesirable. Pressure tests indicated that fruits growing under a higher degree of moisture were softer and more susceptible to soft scald. Drier plots produced fruits more acid and better flavored. The general consensus of opinion is that excessive irrigation may have a detrimental effect. Apple trees, as a result of their deeper rooting system, have access to a much larger water reserve than herbaceous plants, and therefore any moisture changes are not quickly apparent in the fruit.

### Storage

Gunness, Cole and Roberts (1939) have described the effect of storage on apples as follows:

An apple grows as a part of a living organism—the tree. Before harvest it continues to receive materials from the tree and the net result of these life processes is growth and increased weight. After removal from the tree, life must be sustained on food stored in the apple. Life processes are destructive, and when they have run their course, the apple dies. This natural breakdown of the apple is marked by a gradual darkening of the flesh beginning at the core, and may occur without rotting. Frequently, decay organisms attack the apple and it rots before its food reserves are completely exhausted.

The changes that take place within the apple are the result of chemical reactions. The important constituents affecting the quality of an apple are starch, sugars, acids, tannins, pectins, and esters which are compounds responsible for the characteristic odor and flavor of a particular variety. Quality in an apple depends chiefly upon the proportions of sugars and acids. Prior to harvest, an apple contains a relatively large quantity of starches. In the process of ripening, the starches change to sugars and the acids and tannins diminish, thus making the apple more agreeable to eat. Changes in the character of the pectins are believed to be responsible for the "mealy" or granular condition of the flesh as apples become overripe. Chemical changes within the apple are accompanied by the utilization of oxygen and the evolution of carbon dioxide. This process is known as respiration and is a measure of the speed of ripening. These chemical changes are hastened by heat and retarded by cold. If left in the orchard, an apple may reach its maximum quality for human consumption in early autumn. If exposed to low temperatures before that maximum is reached, development may be retarded and a condition of prime eating quality reached in February or March instead of September or October.

This is the function of storage. No method has yet been discovered by which life processes in an apple may be stopped and the apple held indefinitely at one stage of development without killing it. The progression must go on, but efficient storage slows it down to a marked degree.

There is ample evidence that storage brings marked changes in apples. The factors influencing the storage qualities of apples, according to Wallace (1930) can be summarized as follows:

- (a) Material — variety and age of tree.
- (b) Environmental. These may be further divided into two subgroups:
  1. Natural conditions — including the climatic factors, soil, pests, fungi, etc.
  2. Artificial factors introduced by the grower — including soil treatment, other operations, picking, and handling.

Carlsen (1946) reported that a gradual reduction of temperature from 45° to 36° to 31° F. will keep Delicious apples in better condition than any other practice, except immediate storage at 31° F. The age of the apple after picking can be measured by the structural changes within the apple as shown by increases in the soluble pectin content determined by chemical analyses. The softening of the flesh which accompanies ripening or maturity is due to gradual increase in the soluble pectin content. These changes take place much more rapidly and completely in so-called early and summer varieties such as Yellow Transparent, Red Astrachan, Williams, etc. The rate of softening is closely related to temperature of storage.

Fellers, Cleveland and Clague (1933) found that apples tend to decrease in ascorbic acid content during storage. This change varies to some degree with the variety and takes place more rapidly at warm storage temperatures. Baldwin apples had lost about 20 percent of their vitamin C content after 4 to 6 months' storage at 36°F., and after 8 to 10 months the loss had reached nearly 40 percent. At a storage temperature close to 32°F. there is but little loss of ascorbic acid. At warmer storage temperatures the loss may be as much as 50 percent after 6 to 8 months. According to Thornton (1938) no loss of ascorbic acid occurred in apples stored in an atmosphere of carbon dioxide. Todhunter (1937) found that Delicious apples kept for one year at 45°F. retained approximately only half of their original vitamin C content. Other investigators have reported similar findings in respect to changes in the ascorbic acid content of apples during storage.

## EFFECT OF PROCESSING AND COOKING ON COMPOSITION AND NUTRITIVE VALUE

### Cooking

Apples tend to lose certain of their nutrients during cooking as do other foods. So far as the apple is concerned, ascorbic acid (vitamin C) is probably the nutritive element that shows the greatest change during cooking. The other nutrients can be expected to be quite stable with the exception that some water-soluble materials may be leached from the apple if it is cooked in an excess of water or syrup. However, ordinarily apples are not cooked by methods which would lead to an excessive leaching of nutrients.

Fellers, Isham, and Smith (1933) and Todhunter (1935) found that a considerable amount of the original ascorbic acid of fresh apples was retained when they

were made into applesauce or baked in pie. Baked apples were found to retain a much higher percentage of their original ascorbic acid. Curran, Tressler and King (1937) reported a 20 to 30 percent loss of ascorbic acid when Northern Spy apples were made into applesauce and 80 percent loss when these apples were baked or made into pies. After 48 hours at room temperature the vitamin C content of apple pie filling had been reduced to 12 percent of the original. They concluded that the factors influencing the loss of ascorbic acid were the length of the cooking period, the relatively slow rate of heat penetration with corresponding delayed effect on oxidase enzymes, and the presence of atmospheric oxygen. Kohman (1937) indicated that ascorbic acid would be better retained if apples were immersed in a salt solution before processing.

According to Pfund (1939) good flavor in cooked apples is associated with relatively high acidity (pH 3.1 to 3.4), firmness of the raw fruit, short storage periods, aromatic and spicy qualities, retention of natural flavor of the raw fruit, pleasant texture, and, for applesauce, a lack of thickness in consistency. The flavor of apples cooked after January was considered unsatisfactory if the flavor procurable before and during January was used as a criterion. Pleasant texture in cooked apples was associated with relatively high acidity (pH less than 3.3), short storage periods, tenderness in the raw fruit, juiciness, fineness, mealiness, and, for applesauce, a lack of thickness in consistency. Coarseness was more undesirable in applesauce than in baked apples, but dryness of applesauce was masked by the addition of water during preparation. Texture in cooked apples, like flavor, was less agreeable after January; but, unlike flavor, it may be comparatively satisfactory for some varieties through March.

The food value of certain cooked apple products, as reported by Taylor (1942) is shown in Table 11.

### Apple Products

#### Cider

Clague and Fellers (1936) determined the more important physical and chemical characteristics of cider made from different varieties of apples grown in Massachusetts. Their data are shown in Table 12. In a discussion of the nutritive value of cider they pointed out that apple cider should be sold on its merits as a pleasant, refreshing beverage and not primarily because of its nutritional properties. The vitamin C content of cider was found to be quite low.

#### Apple Juice

Apple juice (a term usually applied to clarified and bottled or canned cider) has essentially the same composition and food value as the cider from which it was made. Esselen (1945) reviewed methods used in the production of apple juice and made suggestions for the improvement of this product, particularly as regards the use of McIntosh apples grown in this locality. The results of this work were summarized as follows:

The flash-heating method of clarification has been found to be particularly effective for apple juice. Apple juice clarified by this method showed no tendency to throw down a sediment during storage and was superior in flavor to juices clarified by other methods.

The temperature of extracting apple juice and the speed with which it is flash-heated after extraction influence the rate of oxidation and subsequent flavor of the finished product. By taking these factors into consideration

TABLE 11.—FOOD VALUE OF COOKED OR PREPARED APPLE PRODUCTS  
(Taylor, 1942)

Product	Weight		Approximate Measure	Calories	Protein	Calcium	Iron	Vitamin A	Thiamin	Ascorbic Acid	Riboflavin
	grams	ounces									
Baked Apple.....	132	4.6	1 medium apple	160	0.5	10.0	0.45	90	.034	2.0	.038
Apple Juice.....	235	8.3	1 cup	118	0.2	15.0	0.66	135	.047	12.0	.071
Applesauce.....	126	4.4	$\frac{1}{4}$ cup	135	0.5	10.0	0.45	90	.034	5.0	.038
Applesauce cake.....	23	0.8	1 piece, $1\frac{1}{2}'' \times 3\frac{3}{4}'' \times 1\frac{1}{2}''$	100	1.1	3.0	—	50	.012	—	.009
Cider, sweet.....	170	6.0	1 glass	85	0.2	—	—	—	—	8.0	—
Apple fritters.....	24	0.8	1 slice apple, $2\frac{3}{4}''$ in diameter, $\frac{1}{8}''$ thick	50	0.5	5.0	0.16	35	.012	1.0	.018
Apple pie.....	157	5.5	$4\frac{1}{2}''$ sector	300	3.2	12.0	0.60	150	.029	1.0	.027
Apple pie.....	100	3.5	$3\frac{1}{2}''$ sector	230	2.3	9.0	0.46	115	.022	1.0	.021
Salad, apple and carrot*.....	82	2.9	$\frac{1}{4}$ cup	100	0.6	22.0	0.40	1,335	.072	5.0	.081
Salad, apple and cabbage*.....	125	4.4	$\frac{1}{4}$ cup cabbage	150	1.4	41.0	0.80	165	.090	40.0	.099
Salad, Waldorf*.....	114	4.0	$\frac{1}{4}$ large apple $\frac{1}{4}$ cup	185	1.9	49.0	0.76	165	.078	8.0	.063

\*With mayonnaise

TABLE 12.—COMPOSITION OF JUICES MADE FROM SEVERAL VARIETIES OF MASSACHUSETTS APPLES  
(Clague and Fellers, 1936)

Variety	Specific Gravity		Degrees Brix		pH		Viscosity		Pectin, Percent		Tannin, Percent		Total Acid, Percent		Ash, Percent	
	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934
Baldwin.....	1.055	1.041	14.1	11.8	3.2	3.5	3.8	3.2	.10	.10	.08	.06	.56	.48	.16	.19
Ben Davis.....	1.045	1.045	10.9	11.5	4.0	3.7	4.2	3.8	.08	.31	.05	.06	.33	.43	.20	.16
King.....	1.055	1.050	12.5	12.9	4.0	3.6	5.1	7.3	.18	.26	.04	.07	.40	.53	.16	.17
McIntosh.....	1.045	1.040	12.2	11.5	3.1	3.5	4.3	4.6	.18	.11	..	.08	.41	.48	.24	.15
Northern Spy.....	1.045	1.045	11.8	12.0	3.2	3.4	4.0	2.2	.08	.09	.08	.08	.48	.49	.18	.13
Rhode Island Greening	1.045	1.045	11.2	12.0	3.2	3.5	4.7	5.6	.16	.30	.04	.07	.44	.47	.14	.12
Roxbury Russet.....	1.065	1.065	15.5	16.0	3.9	3.3	5.1	4.7	.18	.32	.07	.06	.61	.67	.15	.15
Wealthy.....	1.040	1.045	9.8	11.5	3.6	3.3	4.7	4.2	.15	.28	.05	.05	.57	.61	.23	.19
Crab.....	1.065	.....	16.0	...	...	...	...	...	.09	...	.25	...	.75	...	.38	...
Average.....	1.051	1.047	12.7	12.4	3.5	3.5	4.5	4.5	.13	.22	.08	.07	.51	.52	.20	.16



it may be possible to control to some extent the intensity of fresh apple flavor and cider flavor in processed apple juice. It is possible that other methods of controlling oxidation such as the use of antioxidants or the extraction and handling of the juice in an oxygen-free atmosphere might also be of value in producing an apple juice of light color and fresh apple flavor.

In Massachusetts and New England the McIntosh is the most important commercial apple crop. Unfortunately, the juice of the McIntosh, grown in this area, has a rather insipid flavor and must be blended with the juice of other apple varieties for the manufacture of palatable processed apple juice. Tests have been made to determine the optimum amount of McIntosh apples that can be blended with Baldwin or Delicious varieties to yield a good commercial product. It was found that blends of Baldwins containing up to 60 per cent of McIntosh apples yielded a pleasing product. In such blends it is not recommended that over 25 per cent of Red Delicious apples be used owing to their strong aromatic flavor.

In a recent paper Esselen, Powers and Fellers (1946) reported on the fortification of fruit juices, such as apple juice, with ascorbic acid. It would appear that apple juice deserves consideration, in this respect, because of its increased use as a breakfast juice. Added ascorbic acid in fortified apple juice was well retained during processing and storage. The addition of 195 grams of l-ascorbic acid per 100 gallons of apple juice before pasteurization was adequate to provide a finished product that contained at least 35 milligrams of ascorbic acid per 100 milliliters. Such a fortified apple juice is comparable to orange and grapefruit juices as a source of vitamin C. The addition of ascorbic acid to bottled apple juice also had a marked effect in lightening the color of the juice and in retarding darkening during storage. In the opinion of many people the lighter color in apple juice produced by added ascorbic acid improves its appearance. Added ascorbic acid also had a favorable effect on flavor retention in most cases.

### Canned Baked Apples

Ruffley, Clague and Fellers (1939) found that canned glazed apples retained more vitamin C than did canned baked apples. The average loss of vitamin C for five varieties of canned baked apples was 65 percent, and in the canned glazed apples 44 percent. The percentage composition of canned baked Northern Spy apples is shown in Table 13.

Varieties of apples found suitable for canning after baking or glazing were those relatively high in pectin and acid content such as Baldwin, York, Rhode Island Greening, Gravenstein, and Northern Spy.

TABLE 13.—COMPOSITION OF CANNED BAKED NORTHERN SPY APPLES  
(Ruffly, Clague, and Fellers, 1939)

Water.....	72.31 percent
Protein (N x 6.25).....	0.20 percent
Crude Fat.....	0.26 percent
Ash.....	0.19 percent
Crude Fiber.....	0.65 percent
Total Carbohydrates.....	27.04 percent
Acid (as Malic).....	0.31 percent
Fuel Value per 100 Grams.....	113.10 calories

TABLE 14.—AVERAGE COMPOSITION OF CANNED APPLE PRODUCTS  
(American Can Company, 1943)

Product	Type of Pack*	Number of Analyses	Moisture	Total Solids	Ash	Fat (Ether Extract)	Protein (N x 6.25)	Crude Fiber	Carbohy- drates by Dif- ference	Calories	
										Per Gram	Per Pound
			percent	percent	percent	percent	percent	percent	percent		
Apples, baked.....	AS	1	67.1	32.9	0.3	0.4	0.7	0.7	30.8	1.3	588
Apple juice.....	NS	2	88.5	11.5	0.2	0.1	0.1	trace	11.2	0.5	206
Apple rings.....	NS	1	87.4	12.6	0.2	0.3	0.1	1.0	11.0	0.5	213
Applesauce.....	NS	3	88.1	11.9	0.2	0.2	0.3	0.6	10.2	0.4	197
Applesauce.....	AS	2	75.7	24.3	0.2	0.1	0.2	0.5	23.1	1.0	426
Applesauce.....	JP	—	87.3	12.7	0.3	0.2	0.2	0.6	11.4	0.5	230
Applesauce, chopped.....	AS	1	85.8	14.2	0.4	0.7	0.1	2.1	10.9	0.5	228
Applesauce, strained.....	NS, NSA	2	87.9	12.1	0.3	0.2	0.2	0.6	10.8	0.5	207
Applesauce, strained.....	NS, SA	1	87.9	12.1	0.2	trace	0.3	0.5	11.1	0.5	209
Applesauce, strained.....	AS	3	85.2	14.8	0.3	0.4	0.2	1.1	13.0	0.6	251
Applesauce, strained.....	AS, SA	1	79.2	20.8	0.8	0.8	0.2	1.0	17.5	0.8	354

\* AS — added sugar  
JP — juice packed  
NS — no added sugar  
SA — salt added

APPLES AS FOOD

### Canned Apples and Applesauce

In general the composition of canned apples or applesauce is essentially the same as that of the apples from which they are made. The addition of sugar, syrup, or water in the preparation or canning of these products will alter their composition accordingly. Except for ascorbic acid, the other nutrients of the apple can be expected to be reasonably stable in the canned product. The composition of several canned apple products, as summarized by American Can Company (1943), is shown in Table 14.

### Dried Apples

Dried apples are a much more concentrated source of nutrients than are raw apples, owing to the removal of moisture. However, in actual use they are usually rehydrated and so tend to resemble the fresh product in composition. The average proximate composition of dried apples, as reported by Chatfield and Adams (1940) is shown in Table 15. The composition of dried apple powder as reported by the American Medical Association (1939) may be seen in Table 16.

TABLE 15.—PROXIMATE COMPOSITION OF DRIED APPLES  
(Chatfield and Adams, 1940)

Moisture.....	23.0 percent
Protein.....	1.4 percent
Fat.....	1.0 percent
Ash.....	1.4 percent
Carbohydrates, Total.....	73.2 percent
Fiber.....	4.6 percent
Sugars.....	54.0 percent
Acid (as Malic).....	2.3 percent
Fuel Value	
Per 100 grams .....	307.0 calories
Per pound .....	1,395.0 calories

### PHYSIOLOGICAL AND THERAPEUTIC PROPERTIES OF APPLES Calcium Retention

Mindell, Esselen and Fellers (1939) found that the addition of apples or cranberries to the diet of albino rats appeared to increase the amount of calcium absorbed by the animals. It was suggested that the increased calcium retention resulting from fruit diets might be due to an increased acidity of the intestinal tract as had been reported by Esselen (1937) and Sullivan and Manville (1938). Another possibility suggested was that the calcium of the diet might have reacted with the acid of the fruit to form more soluble calcium compounds.

TABLE 16.—COMPOSITION OF APPLE POWDER  
(American Medical Association, 1939)

Moisture.....	2.0	percent
Total solids.....	98.0	percent
Ash.....	1.8	percent
Fat (ether extract).....	2.5	percent
Protein (N x 6.25).....	1.5	percent
Crude fiber.....	6.7	percent
Reducing sugars (before inversion..) .....	52.0	percent
Sucrose.....	17.1	percent
Pectin (alcohol precipitate).....	5.2	percent
Uronic acids.....	9.2	percent
Total carbohydrates (by difference).....	84.1	percent
Tannin and coloring matter.....	1.4	percent
Total sulfurous acid.....	0.01	percent
Total acidity (as malic).....	2.9	percent
pH.....	3.5	
Alkalinity of ash, equivalent to 240 cc. of 0.1 N acid/100 gm. powder.		
Sodium.....	0.11	percent
Potassium.....	0.87	percent
Calcium.....	0.015	percent
Magnesium.....	0.029	percent
Copper.....	0.0008	percent
Iron.....	0.0125	percent
Phosphorus.....	0.0014	percent
Chloride.....	0.216	percent
Total sulfur.....	0.137	percent
Silica (SiO <sub>2</sub> ).....	0.01	percent
Sulfur dioxide.....	0.0004	percent
Calories.....	95.0 per ounce	3.7 per gram

### Treatment of Intestinal Disturbances

According to Manville, Bradway and McMinis (1937), it is in the German folk customs that the idea of using the apple in specific ailments originated. The suggestion of treating the acute digestive disturbances accompanied by diarrhea, which are so frequent in childhood, with bananas, orange juice, or raw apple, either alone or all together, was made by Fanconi (1930). About this time Moro (1929) and Heisler (1930) promulgated their raw-apple therapy for diarrhea of young children, based on the old custom among German peasants of using raw apple for this disorder.

A review of the literature indicates at least five factors which have been suggested as being responsible for the beneficial action of such fruit diets.

1. Tannic acid and astringency.
2. Cellulose and pectin, which act to scour out the intestines, effectively removing bacteria which are basic causes of difficulty.
3. Effect on the pH (acidity) of the intestinal tract, which may be such as to discourage the growth of bacteria.
4. Carbohydrate content of some fruits, which may act to bring about a change in the intestinal bacterial flora through promoting growth of organ-

isms whose presence creates an unfavorable medium for other types of bacteria.

5. Increased calcium excretion through the mucosa. The increased calcium may inhibit intestinal inflammation and detoxicate amines and phenols by salt formation.

In order to study the beneficial action of fruit diets for intestinal disorders, Esselen (1937) investigated the effect of cranberry, blueberry, and apple diets on the intestinal bacterial flora, intestinal putrefaction, and intestinal acidity of the albino rat. A 20 percent cranberry diet was found effective in reducing the numbers of fecal gas-producing and *Escherichia coli* bacteria. There was also evidence that 20 percent apple, blueberry, and cranberry diets materially decreased intestinal putrefaction. A study of the hydrogen-ion concentrations of the intestinal contents showed that diets of 10 and 20 percent raw cranberry and of 100 percent raw apple significantly increased the acidity of the contents of the cecum and large intestine.

Manville and Sullivan (1940) found that the feeding of a dehydrated apple supplement to rabbits increased the hydrogen-ion concentration of the intestinal contents and changed the intestinal flora from one in which *Escherichia coli* predominated to one in which the acidophilic type of organisms was dominant.

Bergeim, Hanszen and Arnold (1936) referred to the presence of definite communities of bacterial life residing within the lumen of the alimentary canal. A fruit meal of apple or banana was found to bring about a condition in the stomach and intestine that is inimical to the presence of bacteria. Feeding the pulp of one apple, or 70 grams of dried banana to human subjects, prior to the introduction into the stomach of a large number of bacteria, caused a condition in the intestine that resulted in the destruction of all, or nearly all, of the organisms ingested. The *Escherichia coli* were also greatly reduced in the subjects fed fruit pre-meals. The meal of fruit, aside from its acid content was considered to be inimical to bacteria because of the butyric acid derived from it. The authors stated further that a fruit pre-meal also reduces the irritating properties of foods to which an individual may be sensitive.

The use of apple powder in the treatment of diarrhea has been reviewed in some detail by Manville, Bradway, and McMinis (1936b, 1937), and the history of the apple in ancient and modern nutrition has been described by Manville (1936a).

Kertesz, Walker and McCay (1941) observed the effect of feeding applesauce on induced diarrhea in rats in order to determine further how an apple diet acts in this respect. The feeding of commercial canned applesauce resulted in a rapid curing of diarrhea. The experimental results confirmed the opinion held by many investigators that pectin is an effective constituent of the apple diet; but, contrary to the opinion of some investigators, it appeared that pectins were not the sole agents in the apple responsible for the curative effect. It was pointed out that, while the important role of the "fiber" content of various foods has often been emphasized and in turn also enlisted as a possible active principle in the apple diet, this was the first case where its important role in curing diarrhea had been demonstrated. An evaluation of the results indicated that the curative effect of the applesauce depended on the pectins and fibrous materials responsible for its colloidal properties. There was no indication that the presence of uronic acids or tannins had any role in curing the induced diarrhea in rats.

From an investigation of pectin as a detoxication mechanism in the body, Manville, Bradway, and McMinis (1936a) demonstrated that galacturonic acid

(a breakdown product of pectin) is capable of forming conjugation products with toxic materials in the same manner as glucuronic acid. Evidence was also obtained that pectin may exert a protein-sparing action. Foods containing hemicellulose and pectin, such as apples, were considered to have a value separate and distinct from calorie considerations. Manville, Reithel, Yamada, Spencer and Richardson (1940), in further studies on pectin and the detoxication mechanism in rats, guinea pigs, and rabbits, found that apple included in the diet is capable of affording protection against the toxic effects of ingested lead.

From further studies on the relationship of organic acids and pectin to the body's self-regulation defense mechanism, Manville and Sullivan (1940) indicated that the bactericidal effect of such food materials as the apple in the intestine is not so much due to substances contained in them as to factors derived from them by enzymic action.

The American Medical Association (1939) have reviewed the question of the therapeutic value of apples in the light of available information and have pointed out that much more evidence is needed before the precise mechanisms involved are made clear. It was concluded by their Council on Foods that the apple is useful as a therapeutic agent in the dietary management of diarrhea but that the mechanism responsible for the reported success of this diet is not clear. It was further emphasized that the use of the fresh or dried apple does not obviate the necessity for other measures, including parenteral administration of fluids when indicated, the careful selection of a suitable transition diet, and competent pediatric supervision.

### SUMMARY

Apples have been widely used as a food from earliest times. In addition to their aesthetic and appetite appeal they have also a definite food value. Chemical analyses show that the edible portion of the apple is in general similar in composition to many of the other fruits. Although the apple cannot be considered an important source of minerals, its liberal use in the diet does contribute definite amounts of the mineral elements needed by the body.

During the process of digestion the acids of the apple are oxidized, and for this reason apples are considered an alkaline food. Tests with human subjects have shown that a person can eat large amounts of apples with no effect on the alkali reserve of the blood.

The use of raw apple in the treatment of diarrhea dates back many years in Germany and other European countries. Recent scientific evidence points to pectin as one of the substances in the apple which is important in bringing about the beneficial effect. Pectin is thought to exert its effect by removal of toxic substances because of its colloidal properties and buffering action. It may also serve as a source of galacturonic acid. The tannin and acid contents of the apple have also been suggested as an aid in maintaining intestinal tone and motility.

The Council on Foods of the American Medical Association has concluded that the apple is useful as a therapeutic agent in the dietary management of diarrhea.

In addition to their other properties apples also contain their share of the vitamins. When eaten fresh, apples can constitute an important source of ascorbic acid (vitamin C) in the diet. They also contain vitamin A, thiamin, and the other "B-vitamins" in small amounts.

We have always eaten apples for their zest, attractiveness, and flavor. Now with a recognized food value assigned to them we can appreciate apples for their nutritive as well as their aesthetic value.

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