NUTRIENT CHANGES IN FRUITS AND VEGETABLES AFTER PROCESSING

by

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INTRODUCTION

Modern technology has greatly increased the yields of fruits and vegetables. One fourth of the highly perishable produce harvested, however, is never consumed due to spoilage (52). From the time of harvested, the raw plant tissues undergo different changes which may not only decrease their nutritional value but also destroy their identity. For example, the blanching methods, the method of processing and the storage condition and so on all contribute to those changes. So it is the task of food processors to apply appropriate treatments not only to prevent the unwanted changes but also to maximize the product's nutritional value.

Fruits, vegetables and their processed products play an important role in human diets. The main nutritional contribution is to supply vitamins and minerals. The loss of vitamins due to processing can be tremendous. Vitamins are easily destroyed because they are sensitive to the pH of the solvent, to oxygen, light and heat, or a combination of these. For example, carotene can be destroyed by oxidation while vitamin B complex and ascorbic acid are easily destroyed by heat. The minerals are not significantly affected by these chemical and physical treatments. Some may be oxidized to higher valences by exposure to oxygen or light, but there is no convincing evidence that their nutritional value has been affected. For this reason, we shall concentrate mainly on vitamins in relation to their changes after several processing methods.

The main purpose of this study is to evaluate the known effects of processing on the nutritional values of fruits and vegetables, and to indicate how certain processing procedures may be changed to minimize losses in nutritional value.

CHAPTER ONE

EFFECTS OF THERMAL PROCESSING ON NUTRIENTS

Man has developed several techniques to preserve his food supply, most of which require the addition of heat to inactivate enzymes, destroy or reduce undesirable microorganisms, and change the physical conditions of food such as color and texture. However, undesirable changes occur also at the same time with these desirable reactions. One of these changes is the loss of nutrients.

The purpose of thermal processing is to lengthen the storage life of food (36). However, temperature elevation induces and accelerates the degradation of nutrients. Therefore, thermal processing must be optimized to assure maximum nutrient retention while achieving the preservation of food. Thermal processing can be divided into blanching, pasteurization and commercial sterilization. Some of the characteristics of these processes are listed in Table 1 (36).

BLANCHING

The objectives of blanching vary with the product and method of preparation to be used. In freezing vegetables, the inactivation of enzymes is essential because no further heat is employed (52). For canning, blanching wilts the tissue to facilitate packaging, removes tissue gases for filling container, increases the temperature of the tissue prior to container closing, and inactivates enzymes (36).

Table 1

GENERAL CHARACTERISTICS OF THREE THERMAL PROCESSES APPLIED TO FOODS

THERMAL PROCESS	TEMPERATURE	COMMENTS
Blanching	Usually $\leq 100^{\circ}C$	Usually < 10 min. Inactivates enzymes, removes tissue gases, wilts tissue, preheats tissue, other special treatments follow (canning, freezing, dehydration).
Pasteurization	Usually $\leq 100^{\circ}C$	Inactivates vegetative cells of pathogenic or spoilage organisms, other special treatments follow (e.g. refrigeration, fermentation).
Commercial sterilization	Usually $> 100^{\circ}C$	Inactivates spores of pathogenic or spoilage organisms, usually used in conjunction with anaerobic condition.

Source: Lund, D.B. 1977. Food Technol. 31:71.

Although the objectives of blanching vary from product to product, the following functions can be summarized (18):

1) Remove foreign materials including plant juices which may influence flavor.
2) Wilt vegetables so that a proper, uniform fill of container can be achieved.
3) Expel air and other gases which might create excessive pressure in the sealed container.
4) Inactivate enzymes.
5) Decrease the bacterial load.
6) Help clean the product.

EFFECT OF BLANCHING METHODS ON NUTRIENTS

As mentioned previously, various methods are used on different products in order to accomplish the objectives of blanching. The two traditional methods of blanching are hot water and steam as heat transfer medium. The main difference between these two processes with respect to nutrient retention is the extent of leaching. Steam blanching results in greater retention of water-soluble nutrients than water blanching (Table 2), including water-soluble vitamins (22). That can be interpreted easily because the loss of water-soluble vitamins are accelerated by water blanching.

A new steam blanching method called IQB (individual quick blanch), designed to reduce blanching effluent, has recently been developed. With IQB, blanching takes place in two steps: a heating step and a

Table 2

EFFECT OF BLANCHING ON NUTRIENTS

Reference	Product	Nutrient	Process	% Retention
Bomben et al. (5)	Lima beans	Ascorbic acid	S	16
			IQB	24
	Green beans	Ascorbic acid	S	8
			IQB	11
Dietrich and Neumann (13)	Brussels sprouts	Ascorbic acid	W 11min/190°F	70
			S 11min/190°F	76
			W 7min/200°F	67
			S 7min/200°F	76
			W 6min/212°F	69
			S 6min/212°F	72
Dietrich et al. (12)	Brussels sprouts	Ascorbic acid	W 6min/212°F	57.9
			M 1min+ W 4min/212°F	71.6
			M 1min+ W 3min/212°F	70.9
Eheart (14)	Broccoli	Ascorbic acid	W 10min/77°C	61.1
			W 3min/100°C	66.1
			M 2min	79.1
Guerrant et al. (22)	Lima beans	Niacin	W 2min/200°F	1.3
			S 1min/210°F	1.5
	Peas	Ascorbic acid	W 3min/200°F	13.1
			S 3min/210°F	13.2
		Riboflavin	W 3min/200°F	0.4
			S 3min/210°F	0.5
		Thiamine	W 3min/200°F	0.32
			S 3min/210°F	0.37
Raab et al. (48)	Lima beans	Pyridoxine	W 48min/116°C	5.89
			S 48min/116°C	6.25
Ralls et al. (50)	Spinach	Carotene	W	5.4
			Hot gas	3.9
		Riboflavin	W	0.12
			Hot gas	0.10
		Ascorbic acid	W	20.8
			Hot gas	34.2

W= water blanching; M= microwave blanching; S= steam blanching; IQB= individual quick blanching.

holding step. Products are spreaded in a single layer on a belt moving rapidly through a steam chest (31). Therefore, each piece can receive complete and unobstructed steam. After the short exposure to steam, products are transported slowly through heated chamber. The holding time is provided to equilibrate the product temperature at a mass average temperature high enough to stop enzyme activity (5). Lazar et al. (31) stated that the IQB process could also reduce loss of juice into the blancher effluent. This would not only reduce effluent strength but also increase the nutritional value of the IQB-processed products.

Bomben et al. (5) indicated that there may be a slight improvement in ascorbic acid retention with IQB. He also showed that applying warming and partial drying prior to IQB can significantly reduce effluent and also the loss of ascorbic acid. Furthermore, these preconditioned products were more readily individually quick frozen because no ice bonds formed between pieces (31). The reason IQB improves nutrients retention is that with IQB each individual particle receives nearly the same heat treatment. With conventional steam blanching, the particles on the periphery of the bed are generally overblanched while particles in the center of the bed are just adequately blanched (35).

Microwave heating has also been used for blanching food products. Dietrich et al. (12) compared microwave, conventional and combination blanching of Brussels sprouts and found ascorbic acid content was higher after combining blanching by microwave energy with steam or water than after steam or water blanching alone. Eheart (14) reported that the greater retention of ascorbic acid in microwave-blanched broccoli was maintained during storage, but the conventional blanching method was superior to microwave blanching in ascorbic acid retention. Additional information is needed before microwave blanching becomes a commercial method.

Hot gas blanching has also been developed, primarily to reduce effluent generated during the blanching operation. Ralls et al. (49) studied four blanching systems (microwave, hot gas, steam and hot water) to show that only hot gas blanching acted as an effective blanching method which generated almost no liquid waste. They also reported the content of ascorbic acid in spinach was significantly different between hot gas and water blanching methods. The higher percentage retention of ascorbic acid in hot gas blanching was due to the significant retention of blanching effluent (50).

In conclusion, it appears that blanching can significantly reduce the nutrient content of foods. As a matter of fact, the nutrient losses due to blanching is due to thermal leaching and oxidation. Nutrient loss due to leaching is higher during water blanching while greater oxidative loss results from blanching in hot air. Even if we only consider the thermal degradation of nutrients from blanching, it is still difficult to predict an optimum process. However, blanching by the high temperature-short time (HTST) process which will be discussed later would result in better retention of nutrients.

PASTEURIZATION

Pasteurization is a thermal process designed to inactivate part but not all of the vegetative microorganisms present in food. Since the food is not sterile, pasteurization must be accompanied by other techniques to accomplish the preservation operation, such as fermentation for pickles or in conjunction with high acid fruit juice where the environment is not particularly suited for growth of microorganisms (36). The most important reason for pasteurization is to inactivate the vegetative cells which induce food spoilage.

EFFECT OF PASTEURIZATION ON NUTRIENTS

As previously mentioned, pasteurization only inactivates part of the microorganisms. Most food products have a low pH value either naturally or after fermentation to produce an acid condition. Because most of the heat labile nutrients are relatively stable in acid condition, nutrient losses during pasteurization are relatively minor (24).

Although thermal losses during pasteurization may be small, oxidative losses may be high. Thus, products such as fruit juices are always pasteurized in deaerated conditions (62).

COMMERCIAL STERILIZATION

Commercial sterilization inactivates microorganisms or their spores which would grow and produce spoilage during storage (35). Food products are not really sterile since viable spores of micro-organisms are present but they cannot germinate under the conditions of storage. Therefore, commercial sterilization is always used in conjunction with other preservation techniques, usually packaging under anaerobic condition, because (36):

1) Spores of anaerobic organisms are generally less heat resistant than spores of aerobic organisms, resulting in less severe thermal processis;
2) It is relatively easy to maintain an uncontaminated anaerobic condition;
3) It can minimize the oxidative reactions during heating.

The traditional package for maintaining anaerobic conditions is the can or glass container. More recently, plastic and aluminum foil pouches have been used (36).

EFFECT OF COMMERCIAL STERILIZATION ON NUTRIENTS

Nutrient losses during canning process ranged from 0 to 90.6% depending on the nutrient and the vegetable (Table 3) (35). To optimize nutrient retention in commercial sterilization, the high temperature short time (HTST) method can result in greater nutrient retention. In a comparison of the HTST process to the conventional method, Everson et al. (15) (Table 4) found that thiamine retention in strained lima beans was improved significantly. In tomato juice

Table 3

NUTRIENTS LOSSES IN CANNING

Product	Biotin[1] (%)	Folacin[1] (%)	B-6[2] (%)	Panto-thenic[2] Acid (%)	A[3] (%)	Thiamin[3] (%)	Ribo-fiavin[3] (%)	Niacin[3] (%)	C[3] (%)
Asparagus	0	75.2	64.0	—	43.3	66.7	55.0	46.6	54.5
Lima beans	—	61.8	47.1	72.3	55.2	83.3	66.7	64.2	75.9
Green beans	—	57.1	50.0	60.5	51.7	62.5	63.6	40.0	78.9
Beets	—	80.0	9.1	33.3	50.0	66.7	60.0	75.0	70.0
Carrots	40.0	58.8	80.0	53.6	9.1	66.7	60.0	33.3	75.0
Corn	63.3	72.5	0	59.2	32.5	80.0	58.3	47.1	58.3
Coropeas	—	36.6	90.6	84.8	83.8	79.1	61.5	68.8	89.7
Mushrooms	54.4	83.8	—	54.5	—	80.0	45.6	52.3	33.3
Green peas	77.7	58.8	68.8	80.0	29.7	74.2	64.3	69.0	66.7
Spinach	66.7	34.7	75.0	78.3	32.1	80.0	50.0	50.0	72.5
Tomatoes	55.0	53.75	—	30.3	0	16.7	25.0	0	26.1

1 Mitchell *et al.* (1968).
2 Orr (1969).
3 Watt and Merrill (1963).

Source: Lund, D.B. 1975. Effect of blanching, pasteurization and sterilization on nutrients. in Nutritional Evaluation of Food Processing. P. 229. eds. by Harris and Karmas.

Table 4

EFFECT OF THERMAL PROCESSING METHODS ON NUTRIENTS

	Thiamine Loss (micrograms/100 grams)		Pyridoxine Loss (micrograms/100 grams)	
Product	HTST	Conventional	HTST	Conventional
Strained lima beans	14.35	42.2	8.25	11.7
Tomato juice concentrate	NS	2.8	NS	NS

NS= not significant.

Source: Everson, G.J. et al. 1964. Food Technol. 18:85-88.

concentrate, almost 100% of the thiamine was retained during processing. Also, HTST did not influence pyridoxine retention or stability. According to Lund (35) who compared the activation energies for microorganism destruction to the activation energies of nutrient destruction, an increase in processing time increased the rate of microbial destruction more so than it did the rate of nutrient destruction. Chichester (7) also reported that a 10°C rise in processing temperature resulted in almost a 10-fold increase in bacterial destruction but only a doubling in chemical reaction leading to the destruction of vitamins. Consequently, HTST results in greater nutrient retention.

Nutrient losses appear to be quite significant in the thermal processing. So altering processing method to maximize nutrient retention is a very important and necessary direction for food processing.

CHAPTER TWO

EFFECTS OF MOISTURE REMOVAL ON NUTRIENTS

Dehydration and concentration are two major processing methods in moisture removal. These two procedures have a wide variety of preliminary processes which can affect the nutritional value of foods. And procedures after dehydration or concentration may be needed. Dehydrated foods, if stored under the proper conditions, will not spoil from microbial attack because the moisture content is low. Concentrated products are usually not stable to microorganisms and are always combined with an additional preservation process (4).

The temperature used during dehydration and concentration varies widely. Generally speaking, high temperature during processing is more favorable for the chemical reactions that reduce nutrients. However, the alternative, low temperature processing is more expensive because of the longer processing time. Furthermore, it is possible that microbial growth will occur during processing (4). Therefore, only methods which reduce the processing time, but have high enough temperature to inhibit microbial growth, will result in the maximum nutrient retention.

CONCENTRATION

Fruit juices are the major products of nutritional significance which can be found in the concentrated form. The obvious advantages of concentrated products are the reduction of weight and volume which can decrease shipping and storage costs. Besides, if products are to be dried after concentration, the total cost of processing will be lower, since part of the moisture has already been removed by concentration.

EFFECTS OF DIFFERENT CONCENTRATION METHODS ON NUTRIENTS

Freeze Concentration

Water may be removed from juices by freezing out as crystals of solid ice (62). This is a relatively new process and useful data concerning its effect on nutrient retention has not appeared in the literature. However, it concentrates fruit juices without significant loss of nutrients and, at a low temperature, the nutrient retention would be near to 100% (55). The only loss would be nutrients remaining in ice crystals and fluid adhering to the ice. The principal disadvantage of freeze concentration of fruit juices is its high capital cost (62).

Evaporation

Evaporation is the most commonly used method for concentrating liquid foods, is the boiling off of the water by elevated temperature. The exact process varies depending on the products and processes (4). Also the equipment is varied and undergoes differnet technical modification in order to minimize the changes during processing.

Since this method evaporates the moisture, volatile components would be significantly changed possibly reducing the flavor of the products. As for the nutritive vlaue, if the products are held at low temperature and pressure, and oxygen and contamination are free, the changes during concentration can be negligible (25). Only cold and frozen storage can hold concentrated products for a long period without significant loss of nutritional value.

DEHYDRATION

Dehydration is an ancient method for preserving foods. Today, the process is valuable because it lowers the costs of packaging, storing, and transporting by reducing the weight and volume of the products (33). Remarkable progress has been made in dehydration technology during the past several years. In most types of drying, the basis is to supply heat to the food and remove moisture in the vapor state. Although dehydrated products are much smaller, these convenience foods are growing now and have a potential for larger markets in the future.

Dehydrated fruits and vegetables are concentrated in nutrients. However, during the process of dehydration, some nutrients may be lost. The extent of vitamin destruction will depend on the material preparation before dehydration, on the dehydration procedure, and on the storage conditions of dehydrated products (52).

Carotene is well retained during dehydration if the products have been blanched (26). The carotene content of vegetables decreases as much as 80% if products have not been blanched. Also if products have been adequately blanched the loss of carotene content can be lowered to 5%, depending on the particular product (52). As a matter of fact, many workers in industry and in research organizations have observed increases in carotene content of vegetables during the dehydration process. Bailey and Dutton (3) reported that the increased carotene content in dehydrated vegetables resulted from losses of soluble solids druing blanching. Carotene is very sensitive to oxidative degradation, sulfur dioxide which is a strong reducing agent, therefore, can be applied to protect carotene losses (52). In conclusion, blanching and product are the two major factors which influence the retention of carotene.

Only moderate losses of thiamine, riboflavin, niacin and pantothenic acid occur during dehydration (26). Under the condition of applying sulfite to prevent browning and to protect ascorbic acid retention, thiamine content can be significantly decreased, because most of the thiamine is destroyed by fission of the molecule (27).

Data in Table 5 show effects of sulfite on retention of vitamins in dehydrated cabbage (41). The thiamine content of sulfited cabbage is considerably less than that of the untreated material. This reduced amount of thiamine disappear almost completely during subsequent storage of these products (37). The higher the concentration of sulfite used, the severer the loss of thiamine (32). In general, if the sulfite treatment is used, thiamine can never be the major nutrient of the product.

Table 5

EFFECT OF SULFITE ON RETENTION OF VITAMINS IN CABBAGE DURING BLANCHING AND DEHYDRATION

Treatment	No. of samples	Content of vitamins expresses as mg/100 g dry matter			
		Ascorbic acid	Thiamine	Riboflavin	Niacin
Unsul-fited	4	189	0.41	0.37	2.4
Sulfited	4	351	0.13	0.37	2.7

Source: Pavcek, P.L. 1946. Ind. Eng. Chem. 38:854.

Ascorbic acid is the most difficult vitamin to preserve during dehydration of fruits and vegetables. Loss varies with the products. According to Steven's demonstration (54), onions and peas did not lose ascorbic acid during drying while corn and sweet potatoes lost over 60%. However, a short drying time can help to retain higher ascorbic acid (52). In addition, ascorbic acid also can be destroyed by browning reaction (62). So by retarding the browning reaction, an increase in the ascorbic acid retention will occur. Ascorbic acid is considerably enhanced due to the addition of sulfite to retard browning reaction (Table 5). And the presence of sulfite, if maintained during storage, also assures better retention of ascorbic acid (41).

The potential of superheated steam for drying has been discovered for many years. The greater drying rates and thermal efficiencies are possible when drying with superheated steam than with air (30). Yoshida and Hyodo (63) listed the advantages of superheated steam in relation with nutrients as following:

1) There is less oxidation in food when superheated vapor is used.
2) Drying material exhibits high evaporation rate.

Drying material in superheated steam involves two processes — heating with steam and rapid drying while air drying involves the process of drying only. In a comparison of the effects of these two methods on potaot slices (63), the product dried with superheated steam had less oxidative browning, and higher ascorbic acid than that dried with air at the same condition.

In conclusion, ascorbic acid loss is high in drying without sulfite treatment but concentration has minimal loss. The primary loss in dehydration is due to oxidation which especially decreases the amount of ascorbic acid. Methods which can improve ascorbic acid retention would probably serve the same purpose for other nutrients.

CHAPTER THREE

EFFECTS OF FREEZE-PRESERVATION ON NUTRIENTS

Two important methods developed by man to extend the storage life of foods are heat (discussed in Chapter one) and cold. Food preserved by elevated temperature are always accompanied with undesirable changes. Preservation by low temperature is generally regarded as the best method for both short and long term preservation because low temperature retards the rate of chemical and physical reactions to the food products.

Freezing was recognized as an excellent method of preserving food for many years. However, it did not become important until mechanical freezing systems were developed (59). The frozen vegetable pack increased from about 308 million pounds in 1945 (59) to 512 billion pounds in 1973 (2). These figures indicate that the growth trend of freezing preservation is increasing rapidly. And I believe that its importance will continue to increase in the future.

EFFECT OF BLANCHING AND COOLING

Most vegetables are blanched prior to freezing. This heat treatment almost precooks vegetables and makes them porous (58). Therefore, the water soluble nutrients become more subject to leaching after blanching. However, this process can not be avoided because it inactivates enzymes which would catalyze the nutrients degradation during storage. Table 6 clearly shows the advantage of blanching during the freeze-preservation process. The results show that blanched vegetables retain nutrients much better during low temperature storage than those that are not blanched before freezing. Zscheile et al. (64) stated that the practice of blanching before freezing retarded the loss of carotene, and it was most effective during the first year of storage.

Rapid cooling is required immediately after blanching in order to avoid overcooking and growth of microorganisms which is possible in slow cooling process (33). As expected, overcooking and growth of microorganism enhance nutrient losses.

EFFECT OF FREEZING ON NUTRIENTS

The loss of vitamins that occur in vegetables during the freezing process are shown in Table 7. The values reported are percentage losses during freezing. The results show that freezing causes almost no nutrient losses. In observing the data, it should be kept in mind that the data were not obtained from uniform sampling time after freezing. For example, the data of Van Duyne's (60) are 20 hours after freezing while Tinklin and Filinger's (57) are 24 hours after freezing. Therefore, these instances involve a holding period before the data analysis that may slightly reduce the nutrient content. However, it can concluded that loss of vitamins during freezing are negligible.

LOSS OF NUTRIENTS DURING FROZEN STORAGE

Table 6

EFFECT OF BLANCHING ON LOSS OF VITAMINS DURING FROZEN STORAGE

Reference	Product	Treatment	Storage condition	Vitamin	% Loss
Farrell and Fellers (17)	Green snap beans	Blanched	-20°C, 1yr.	Thiamine	22
		Unblanched			74
		Blanched	-20°C, 1yr.	Riboflavin	3.0
		Unblanched			39.0
		Blanched	-20°C, 1yr.	Ascorbic acid	47.0
		Unblanched			90.5
Zscheile et al. (64)	Beans	Blanched	-20°C, 6mo.	Carotene	49.2
		Unblanched			84.8
	Asparagus	Blanched	-20°C, 8mo.	Carotene	29.3
		Unblanched			74.7
	Spinach	Blanched	-20°C, 6mo.	Carotene	5.2
		Unblanched			48.1

Table 7

VITAMIN LOSSES DURING FREEZING

Reference	Product	Vitamin loss %				
		Riboflavin	Thiamine	Niacin	Carotene	Ascorbic acid
Van Duyne et al. (60)	Peas	4				
	Soybeans	3				
	Spinach	3				
Guerrant et al. (23)	Peas	3	1	14	0	12
	Lima beans	5	4	3*		18
Retzer et al. (51)	Cauli-flower					1*
	Snap beans					0
Tinklin and Filinger (57)	Spinach					1
Gordon and Nobel (21)	Asparagus					6
	Broccoli					3*
	Brussels sprouts					4
	Cauli-flower					5
	Green beans					6

*Nutrients in blanched and frozen products are higher than those in blanched alone.

In Table 8 (11), retention of nutrients during storage in control (product held at $0^{o}F$ throughout the study) were compared to those in variation samples which were held in storage at $0^{o}F$ for 2, 5 and 11 months and were exposed to $20^{o}F$ for 1 month at the end of these periods (11). The greatest effects of storage are observed in the case of ascorbic acid, but in general there was good vitamin retention on products which were stored for 12 months at $0^{o}F$.

The effect of storage temperature on loss of ascorbic acid are shown in Figure 1 and 2 (20). These two figures clearly indicate that storage at high temperature can cause marked vitamin losses.

COMPARATIVE LOSSES OF VITAMINS DURING VARIOUS METHODS OF PRESERVATION

Table 9 (61) compares the losses of vitamins during various methods of preservation. The data indicate that vitamins are preserved at lower concentration in canned vegetables than in frozen vegetables. The concentration of vitamins in frozen vegetables could be enhanced significantly if the process of blanching and cooling are adequately modified.

Data to compare vitamin losses from fruits during various methods of preservation are shown in Table 10 (61). The concentration of ascorbic acid in frozen fruits is higher than that in canned and dried fruits. The data in Table 11 shows the losses of vitamin B_6 and pantothenic acid occur in frozen and canned foods (53). It also indicates that frozen foods have better nutrient retention than canned foods.

Table 8

COMPARATIVE RETENTION OF VITAMINS HELD AT 0°F AND 20°F

(Expressed as % retention in control: % retention in variation sample)

Frozen Food Stored, Months	Vitamins							
	Ascorbic acid	β-Carotene	Folic acid	Niacin	Pantothenic acid	Riboflavin	Thiamine	Vitamin B_6
Green beans, French style								
3	61:34	80:63	100:100b	100a:100b	49:32	100:100	100:100b	100a:100b
6	56:31	47:43	100a:39	100a:100b	84:84	91:100	100a:88	88:78
12	48:24	77:73	94:100b	100a:100b	47:43	100:91	100:100b	79:79
Orange juice, concentrate								
3	101:99	67:67	100:100	79:61	87:87	100a:100b	81:81	100a:104
6	97:95	a	100:100	91:91	79:79	100a:100b	74:77	100a:100b
12	98:96	33:33	100:100	100a:100b	100a:100b	100a:100b	70:74	100a:100b
Peas, green sweet								
3	83:52	85:85	88:63	100a:100b	73:47	100:92	100a:103	100a:100b
6	88:48	85:83	50:25	100a:100b	100a:96	92:83	100a:100b	91:100b
12	89:36	96:90	100:94	102:99	71:60	100a:100b	97:100b	93:91
Strawberries, sliced								
3	87:84	100:100	100a:100b	100a:100b	68:67	67:67	100a:100b	100a:100b
6	86:78	a	100a:100b	100a:100b	79:77	67:67	100a:100b	81:92
12	87:80	a	100a:100b	100a:100b	59:64	56:56	100:100b	83:85

100a expresses retentions in control samples of more than 104%, while 100b does the same for variation samples.

Per cent retentions greater than 100 for both control and variation samples are attributable to minute amounts of some test components, to errors in assaying minute quantities, and to package variability within a given case of samples processed from the same lot of raw material.

[a]Insufficient to measure.

Source: Derse and Teply. 1958. J. agr. Food Chem. 6:311.

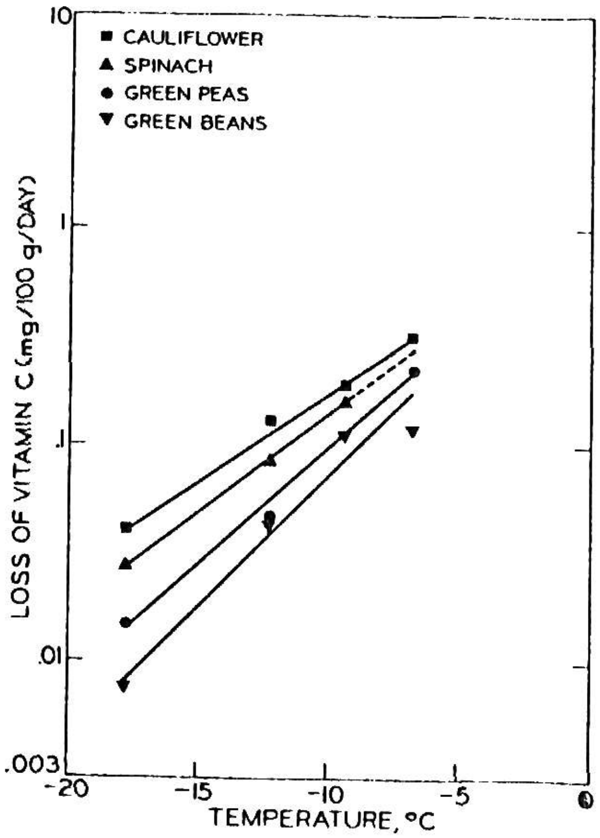

Fig. 1. TEMPERATURE DEPENDENCE OF ASCORBIC ACID DEGRADATION IN FROZEN VEGETABLES

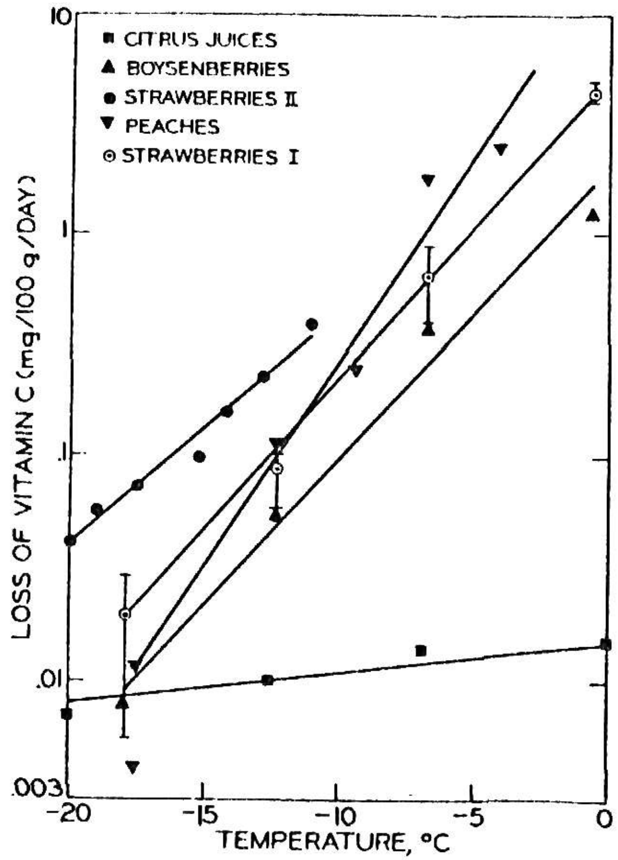

Fig. 2. TEMPERATURE DEPENDENCE OF ASCORBIC ACID DEGRADATION IN FROZEN FRUITS

Source: Fennema, O. 1975. Effects of freeze-preservation on nutrients. in Nutritional Evaluation of Food Processing. p. 352 and p. 265. eds. by Harris and Karmas.

Table 9

COMPARATIVE RETENTION OF VITAMINS BY VEGETABLES DURING CANNING AND FREEZING

Methods of preservation	No. of vegetables	Carotene	Vitamin retention mg/100 g Thiamine	Riboflavin	Niacin	Ascorbic acid
Frozen[1]	4*	337.5	0.13	0.07	1.18	16.25
Canned[2]	4*	134	0.04	0.05	0.75	10

[1]Products were not thawed.

[2]Products contained solids and liquid.

*Products were asparagus, sweet corn, lima beans and potatoes.

Source: Data from USDA Handbook 8 (Watt and Merrill 1963). Based on edible portions of vegetables, 100g.

Table 10

COMPARATIVE RETENTION OF VITAMINS BY APPLE, APRICOT, AND PEACH DURING VARIOUS METHODS OF PRESERVATION

	Vitamin retention mg/100 g				
Methods of preservation	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic acid
Canned*	773.33	0.02	0.02	0.5	2.67
Dried@	7400	0.03	0.16	3.03	13.33
Frozen#	783.33	0.01	0.04	0.57	25

*Products contained solids and liquid.

@Products were sulfured and uncooked.

#Products were not thawed.

Source: Data from USDA Handbook 8 (Watt and Merrill 1963). Values based on edible portions of fruits, 100g.

Table 11

VITAMIN B_6 AND PANTOTHENIC ACID LOSS FROM FROZEN AND CANNED FOODS, MICROGRAMS PER GRAM

Food	Vitamin B_6			Pantothenic acid		
	Raw	Frozen	Canned	Raw	Frozen	Canned
Vegetables, legumes						
Beans, lima	1.70	1.50	0.90	4.70	2.40	1.30
Beans, common	5.60			2.25		0.61
Beans, green	0.80	0.70	0.40	1.90	1.35	0.75
Beans, yellow		0.79	0.42	2.50	1.38	
Cowpeas	5.62	1.10	0.53	10.50	4.00	1.62
Peas, green, young	1.60	1.30	0.50	7.50	2.15	1.50
Mean	2.43	1.08	0.55	5.73	2.46	1.16
% Loss		55.6	77.4		57.1	77.8
Vegetables, green						
Asparagus	1.53	1.55	0.55	6.20	4.10	
Broccoli	1.95	1.50		11.70	4.50	
Brussels sprouts	2.30	1.75		7.23	4.20	
Cabbage	1.60		1.30	2.05		0.93
Cauliflower	2.10	1.90		10.00	5.40	
Kale	3.00	1.85		10.00	3.76	
Mustard greens		1.33		2.10	1.64	1.50
Okra	0.75	0.45		2.60	2.15	
Rhubarb	0.30	0.25		0.85	0.70	
Spinach	2.80	1.90	0.70	3.00	1.30	0.65
Squash, summer	0.82	0.63		3.60	1.73	
Squash, winter	1.54	0.91		4.00	2.82	
Turnip greens	2.63	1.00		3.80	1.40	0.68
Pepper, red				2.71		0.92
Tomatoes	1.00	0.90		3.30		2.30
Mushrooms	1.25	0.60		22.00		10.00
Mean	1.69	1.07	0.85	5.42	2.81	2.43
% Loss		36.7	57.1		48.2	56.4
Fruit and fruit juices						
12 varieties, mean	0.55	0.47		1.37	1.27	
% loss		15.4			7.2	
24 varieties, mean	0.57		0.35	2.00		0.99
% loss			37.6			50.5

Source: Schroeder, H.A. 1971. Am. J. Clin. Nutr. 24:564-565.

All these comparative data as previously mentioned should be accepted with some caution since large variances can occur depending on the product and conditions.

In conclusion, chemical reactions are indeed reduced at low temperature, but not stopped completely. However, low temperature is perhaps the most applicable method of preservation and storage with minimal change in food composition.

CHAPTER FOUR

EFFECTS OF FERMENTATION ON NUTRIENTS

The technology of fermentation used for food preservation has been applied since prehistoric times. No precise date can be estimated for the origin of fermented vegetables. It was presumed that fermented vegetables originated in the Orient.

Today, this method still plays an important role in our food industries, but the purpose employed has been expended to improve flavor, and prepare beverages in addition to preserve foods. The consumption of these fermented food products has increased in recent years. It is estimated that at least 75% of American families eat fermented vegetables (pickles, sauerkraut etc.) at least once a week (43).

FERMENTED VEGETABLE PRODUCTS

Fermented vegetables are almost all preserved by brining or salting process which undergoes fermentation by lactic acid forming procedure. Therefore, the whole process involves three methods, i.e., brining, salting and acid formation. According to Pederson (42), this preservation is "dependent upon the combined effect of salt, acid, carbon dioxide, low-oxidation-reduction potential, and other minor factors".

Pickles

This is one of the major fermented vegetable products. According to Pederson (43): a pickle is an edible product that has been preserved and flavored in a solution of brine and edible acid such as vinegar. Since 1931, the increase in consumption of pickles in the U.S. has exceeded that of nearly all other food commodities. Since 1955, pickle consumption has increased over 100%.

The names of the pickles are always confused. According to Fabian and Switzer (16), they classified pickles under three general types:

1) The fermented fresh cucumber pickle, such as genuine dill pickles.
2) The unfermented fresh cucumber pickle— fresh cucumber packed in containers to which is added a flavoring liquor. The jars are then sealed and pasteurized immediately to prevent fermentation from occurring, such as pasteurized dill pickles.
3) Pickles are made from "salt-stock". Fresh cucumbers are salted in a brine which is gradually increased in strength until it is approximately 15 to 16% salt. During this salting procedure, pickles undergo fermentation and a curing procedure until curing is complete. Then these products are known as salt-stock. Salt-stock is soaked in water to remove most of the salt then finished by the addition of suitable spice or vinegar. Examples of this type are sour, and sweet pickles.

Camillo et al. (6) analysed pickles to determine the influence of various manufacturing operations on composition as shown in Table 12.

Table 12

INFLUENCE OF VARIOUS MANUFACTURING OPERATIONS ON COMPOSITION (%)

Analysis	Fresh cucumber	Pasteurized dill pickles	Salt stock	Sweet pickles
Iron*	12.0	18.0	11.6	3.0
Copper*	1.8	2.5	8.4	6.5
Carotene	166.0	292.0	600	409.0
Thiamine	7.0	7.0	1.0	0
Riboflavin@	40.0	15.0	10	10
Ascorbic acid	293.0	180.0	44.8	44.8

*Iron and copper were expressed mg/Kg.

@Riboflavin was expressed in Sherman-Bourquin Units per 100g while other vitamins were expressed in International Units per 100g.

Source: Camillo et al. 1942. Food Res. 7:346-349.

The minerals, such as iron and copper were increased by manufacture, possibly because of the addition of salt and vinegar.

Water soluble vitamins are expected to decrease in amount. This is especially true in salt stock, because the gradually increasing strength of salt make nutrients much easier to leach out. It was observed that carotene content was markedly increased after manufacture. Thiamine content was already very low in salt stock and decreased further in sweet pickles. However, there seemed to be no loss of riboflavin or ascorbic acid during the processing and finishing of salt stock to sweet pickles.

There is relatively little published literature concerning the nutritional effects of cucumber brining and processing in pickle manufacture. The low ascorbic acid content of pickles was reported by Clayton (8). According to her experiment, the loss of ascorbic acid was due to oxidation which was accelerated by the vinegar used. She also pointed out that 6% salt brine could greatly retard the oxidation of ascorbic acid.

In conclusion, water soluble nutrients are regularly leached into the brine during curing and fermentation and are further decreased in the desalting process. So the significance of pickles in our diet is probably to attribute flavor rather than nutrients.

Sauerkraut and Other Vegetables

Sauerkraut is literally "acid cabbage". In general, shredded or chopped cabbage is dry-salted in making kraut while cucumbers, olives and other vegetables are brined (43). The salt is added at a low level, about 2.25%. And the desalting of the product is not required (28). Therefore, the major loss of nutrients, discussed in pickles, due to leaching and desalting can be significantly decreased.

Cabbage is not considered to contain relatively high nutritional value, but it has been reported to be a very good source of vitamin C. Pederson et al. (44) reported that the ascorbic acid content of raw kraut obtained immediately after fermentation was approximately the same as the original cabbage. During storage in the vats after fermentation, the content of ascorbic acid slowly decreased. The loss of 33 to 50% of ascorbic acid in the kraut occurred during vat storage and canning. The longer the kraut is stored, the more ascorbic acid is lost. The content of sodium in sauerkraut is significantly increased due to the addition of salt.

Okra

The main purpose of preservation of okra by salting is to add this salted product into the canned products as seasoning in vegetable soup. The salted okra, therefore, usually contains high salt concentration such as 20% salt and does not undergo desalting process (28). So minimal soluble nutrient losses can be expected from this preservation procedure.

Olive

The nutritional value of fresh olives has received little attention. Likewise, little research has been conducted on the nutrient content of olives after processing. However, if we study the whole procedure for olive processing, the steps in the process are: brining storage, lye treatment and curing in diluted brine (62). From these procedures, we may conclude that regardless of the nutrient content of fresh olives, they will be significantly decreased after processing. However, olive oil is remarkably stable and undergoes little chemical or deteriorative change during processing (28).

FERMENTATION OF ALCOHOLIC BEVERAGE

Alcoholic beverages have been consumed worldwide since prehistoric times. Many of these beverages are popular mainly because of their flavor and taste, for example, wine which has been consumed in human diets for centuries.

In general, grapes are relatively poor in vitamin content. However, the amount of ascorbic acid had been reported to decrease steadily during crushing and fermenting and little or none was preserved in the wine. Pasteurized grape juice retains about 33% the original ascorbic acid (40). Thiamine is a normal component of grapes, but sulfiting, pasteurization and filtering will markedly reduce the thiamine content of grape juice (1). As for riboflavin which is sensitive to light, about 50% is lost by sulfiting or by fining with bentonite (1). When musts were made into wine, the riboflavin content was reported to be increased about 43% in white wine and 704% in red wine (45).

In conclusion, nutrients retained in wine depend on the variety of grape and the steps taken for wine making, such as crushing, pasteurization, fermentation etc.

SUMMARY

This process is to apply methods of acid which is added or formed in nature to control the activity of microorganisms in order to preserve foods. Nutrient losses are largely due to leaching especially water soluble nutrients. Although they may be accelerated by exposure to light and heat. The most important change in the fermentation process is that the process attributes not only to the preservation of foods but to changes in texture and flavor of foods. This makes the food products more attractive and palatable in human diets.

CHAPTER FIVE

EFFECTS OF MISCELLANEOUS GENERAL PROCESSING METHODS ON NUTRIENTS

HIGH SUGAR PRESERVATION

Foods may be preserved with high sugar concentration. Generally speaking, this method is applied to make fun foods, such as candied fruits, jellies, preserves, marmalades etc. There is little data in the literature pertaining to the nutrient content of these high sugar preserved products. Data pertaining to the effects of processing or storage on nutrients in these products is even less.

Citron, orange and peels of lemon are sometimes preserved by brining to make candied fruits. Fellers and Smith (19) found that the fresh unripe citron was very rich in ascorbic acid, but there was very little retention of ascorbic acid content in the brined products and probably none in the candied peel. Carotene content of the green fresh citron was estimated at 0.8 to 1.0 International Unit and that of the preserved peel was only slightly less.

The consumption of high sugar preserved products is relatively small in our diet. The nutritional value of these products is not significantly considered in the diet. This is probably the reason there is very little information in the literature on nutrient losses. However, we may presume that sugar is the principal nutrient presented in these products.

RADIATION TREATMENT

Information about the influences of radiation on nutritional value of fruits and vegetables is relatively poor. However, there are a few data discussing the effect of radiation in pure or mixed solution of vitamins.

Proctor and Goldblith (47) compared the radiosensitivity of niacin, riboflavin and ascorbic acid and concluded that ascorbic acid was the most radiosensitive of the three vitamins. Niacin was more radio-sensitive than riboflavin. The relative radiosensitivies of these three vitamins is shown in Table 13. Although niacin is more radioresistant, when a mixture of ascorbic acid and niacin were irradiated, destruction of niacin occurred (47).

Proctor and O'meara (46) showed that diluted solutions of ascorbic acid were relatively more sensitive to irradiation than were concentrated solutions. The same phenomenon also occurred for niacin and riboflavin.

Irradiated fruit usually shows some loss of ascorbic acid in the juice, but this loss is usually below 10% of the total content (19). The effect of dosages on the ascorbic acid retention is shown in Table 14. Ascorbic acid decreased as higher dosage rates were applied.

Since only meager data appeared in the literature discussing irradiation in relation to the nutrient retention in fruits and vegetables, it is not easy to drawn conclusion. However, Thomas and

Table 13

RELATIVE RADIOSENSITIVITIES OF VARIOUS NUTRIENTS*

		Concentration (microgram/ml)		
Compound	Dosage(r)	Before Irrad.	After Irrad.	Retention(%)
Niacin	400,000	50	50	100
Riboflavin	250,000	50	44.8	89.6
Ascorbic acid	100,000	50	8.55	17.1

*Nutrients were exposed to X-Rays produced at 50Kr.

Source: Proctor and Goldblith. 1949. Nucleonics. 5(9):62.

Table 14

THE EFFECT OF VARIOUS DOSAGES OF IRRADIATION ON ASCORBIC ACID CONTENT IN FLORADEL TOMATOES*

	Ascorbic acid content mg/100g			
Storage (days)	Unirradiated	100 Krads	200 Krads	300 Krads
0	21.5	18.6	18.5	19.6
2	20.7	23.1	19.3	19.1
4	19.6	20.3	21.1	18.5
7	21.0	21.7	20.0	17.9

*Tomatoes irradiated 3 days and stored at 68°F.

Source: Dennison and Ahmed. 1972. Isotopes Radiation Technol. 9:198.

Calloway (56) gave a comparison of ascorbic acid and carotene after various processing treatment. There was no significant advantage of irradiation when compared to dehydration and canning.

CONCLUSION

Harris has stated " if food processing is defined to include all treatments of a foodstuff from the place of origin to the point of consumption, then more than 95% of our food is processed." (24). This statement clearly indicates the importance of processed food in our diet. The stabilities of vitamins, which comprise the major part of nutrient present in fruits and vegetables, undergo different conditions as shown in Table 15 (24). For example, vitamin A rapidly loses activity when heated in the presence of oxygen. Ascorbic acid is stable in acid solution and decomposes in light, and this decomposition is greatly accelerated due to oxygen and alkalines. With these factors in mind, it will be easier to alter processing methods and storage conditions for maximizing nutrient retention.

The previous chapters provide a brief review discussing the influence of various treatment on nutrients and how to minimize nutrient loss of processed products. Numerous foods have been fortified in order to maintain a high nutritional content, such as fruit juices fortified with ascorbic acid. Some products are not suitable for fortification, for example, ascorbic acid added into dehydrated potato granules will create a pink color during storage which is made by oxidation of ascorbic acid (52). Therefore, great effort is needed to retain nutrient content by shortening blanching time, rapid thermal

Table 15

STABILITY OF NUTRIENTS

Nutrients	Effect of pH: Neutral pH = 7	Acid pH < 7	Alkaline pH > 7	Air or oxygen	Light	Heat	Max. cooking loss %
Carotene	S	U	S	U	U	U	40
Vitamin B Complex							
Thiamine	U	S	U	U	S	U	80
Riboflavin	S	S	U	S	U	U	75
Pyridoxine	S	S	S	S	U	U	40
Niacin	S	S	S	S	S	S	75
Pantothenic acid	S	U	U	S	S	U	50
Ascorbic acid	U	S	U	U	U	U	100

S = stable (no important destruction); U = unstable (significant destruction).

Source: Harris and Von Loesecke. 1971. Nutritional Evaluation of Food Processing. P. 2.

processing, proper storage condition etc. Besides these, the geneticist and grower also need to be concerned with the nutritional value of the products rather than yield and appearance only.

REFERENCES

1. Amerine, M.A., Berg, M.S., and Cruess, W.V. 1971. The Technology of Wine Making. 3rd Edition. The Avi Publishing Co., Westport, Conn. pp. 110-111.

2. Am. Frozen Food Inst. 1974. Frozen Food Pack Statistics— 1973. American Frozen Food Institute, Washington, D.C. (Cited from B.S. Luh and J.G. Woodroof 1975. Commercial Vegetable Processing. p. 317.)

3. Bailey, G.F., and Dutton, H.J. 1945. Apparent increase in carotene of carrots during process of dehydration. Fruit Prod. J. 24:138.

4. Bluestein, P.M., and Labuza, T.P. 1975. Effects of moisture removal on nutrients. Pages 289-320 in R.S. Harris and E. Karmas, eds. Nutritional Evaluation of Food Processing. The Avi Publishing Co., Westport, Conn.

5. Bomben, J.L., Dietrich, W.C., Farkas, D.F., Hudson, J.S., De Marchena, E.S., and Sanshuck, D.W. 1973. Pilot plant evaluation of individual quick blanching (IQB) for vegetables. J. Food Sci. 38:590-594.

6. Camillo, L.J., Hoppert, C.A., and Fabian, F.W. 1942. An analytic study of cucumbers and cucumber pickles. Food Res. 7:339-352.

7. Chichester, C.O. 1973. Nutrition in food processing. Pages 318-333 in M. Rechcigl. Food, Nutrition and Health. World Review of Nutrition and Dietetics, Vol. 16.

8. Clayton, M.M. 1940. Foods and nutrition. Maine Agr. Expt. Sta. Bull. 56:231-235.

9. Daoud, H.N., Luh, B.S., and Miller, M.W. 1977. Effect of blanching, EDTA and $NaHSO_3$ on color and vitamin B_6 retention in canned garbanzo beans. J. Food Sci. 42:375-378.

10. Dennison, R.A., and Ahmed, E.M. 1972. Effects of low-level irradiation on the preservation of fruit: A 7-year summary. Isotopes Radiation Technol. 9:195-198.

11. Derse, P.H., and Teply, L.J. 1958. Effect of storage conditions on nutrients in frozen green beans, peas, orange juice, and strawberries. J. Agr. Food Chem. 6:309-312.

12. Dietrich, W.C., Huxsoll, C.C., and Gradagni, D.G. 1970. Comparison of microwave, conventional and combination blanching of Brussels sprouts for frozen storage. Food Technol. 24:613-617.

13. Dietrich, W.C., and Neumann, H.J. 1965. Blanching Brssels sprouts. Food Technol. 19:1174-1177.

14. Eheart, M.S. 1967. Effect of microwave vs. water-blanching on nutrients in broccoli. J. Am. Dietet. Assoc. 50:207-211.

15. Everson, E.J., Chang, J., Leonare, S., Luh, B.S., and Simone, M. 1964. Aseptic canning of foods. Food Technol. 18:84-88.

16. Fabian, F.W., and Switzer, R.G. 1941. Classification of pickles. Fruit Prod. J. 20:136-140.

17. Farrell, K.T., and Fellers, C.R. 1942. Vitamin content of green snap beans. Influence of freezing, canning, and dehydration on the content of thiamine, riboflavin, and ascorbic acid. Food Res. 7:171-177.

18. Feaster, J.F. 1960. Washing, trimming and blanching. Pages 112. in R.S. Harris and H. Von Loesecke, eds. Nutritional Evaluation of Food Processing. John Wiley & Sons, New York. Reprinted in 1971 by Avi Publishing Co., Westport, Conn.

19. Fellers, C.R., and Smith, E.G. 1939. Chemical composition and fermentation studies of citron. J. Agr. Res. 53:859-866.

20. Fennema, O. 1975. Effects of freeze-preservation on nutrients. Pages 244-288 in R.S. Harris and E. Karmas, eds. Nutritional Evaluation of Food Processing. The Avi Publishing Co., Westport, Conn.

21. Gordon, J., and Nobel, I. 1959. Effects of blanching, freezing-storage, and cooking on ascorbic acid retention in vegetables. J. Home Econ. 51:867-870.

22. Guerrant, N.B., Vavich, M.G., Fardig, O.B., and Ellenberger, H.A. 1947. Effects of duration and temperature of blanch on vitamin retention by certain vegetables. Ind. Eng. Chem. 39:1000-1007.

23. Guerrant, N.B., and O'Hara, M.B. 1953. Vitamin retention in peas and lima beans after blanching, freezing processing in tin and glass, after storage and after cooking, Food Technol. 7:473-477.

24. Harris, R.S., and Von Loesecke, H. 1960. Nutritional Evaluation of Food Processing, John Wiley & Sons, New York. Reprinted in 1971 by Avi Publishing Co., Westport, Conn.

26. Hendel, C.E. 1960. Effects of drying and dehydration on food nutrients. Pages 148-156 in R.S. Harris and H. Von Loesecke, eds. Nutritional Evaluation of Food Processing. John Wiley & Sons, New York. Reprinted in 1971 by Avi Publishing Co., Westport, Conn.

27. Hollingsworth, D.F. 1970. Effects of some new production and processing methods on nutritive value. J. Am. Dietet. Assoc. 57:246-249.

28. Jones, I.D. 1975. Effects of processing by fermentation on nutrients. Pages 324-354 in R.S. Harris and E. Karmas, eds. Nutritional Evaluation of Food Processing. The Avi Publishing Co., Westport, Conn.

29. Josephson, E.S., Thomas, M.H., and Calhoun, W.K. 1975. Effects of treatment of foods with ionizing radiation. Pages 393-341 in R.S. Harris and E. Karmas, eds. Nutritional Evaluation of Food Processing. The Avi Publishing Co., Westport, Conn.

30. Lazar, M.E. 1972. Blanching and partial drying of foods with superheated steam. J. Food Sci. 37:163-165.

31. Lazar, M.E., Luh, D.B., and Dietrich, W.C. 1971. A new concept of blanching IQB. Food Technol. 25:684-684.

32. Luh, B.S., Karbassi, M., and Schweigert, B.S. 1978. Thiamine, riboflavin, niacin and color retention in canned small white and garbanzo beans as affected by sulfite treatment. J. Food Sci. 43:431-435.

33. Luh, B.S., and Woodroof, J.G. 1975. Commercial Vegetable Processing. The Avi Publishing Co., Westport, Conn.

34. Lund, D.B. 1973. Effects of heat processing. Food Technol. pp.16-17.

35. Lund, D.B. 1975. Effects of blanching, pasteurization, and sterilization on nutrients. Pages 205-240 in R.S. Harris and E. Karmas, eds. Nutritional Evaluation of Food Processing. The Avi Publishing Co., Westport, Conn.

36. Lund, D.B. 1977. Maximizing nutrient retention. Food Technol. 31:71-74.

37. Mallette, M.F., and Dawson, C.R. 1946. Commercial dehydrated vegetables. Ind. Eng. Chem. 38:439.

38. Mitchell, A.S., Rynbergen, H.J., Anderson, L., and Dibble, M.V. 1968. Cooper's Nutrition in Health and Disease, 15th Edition. J.B. Lippincott Co., Philadephia. (Cited from R.S. Harris and E. Karmas, eds. 1975. Nutritional Evaluation of Food Processing. p. 238.)

39. Orr, M. 1969. Pantothenic acid, vitamin B_6 and vitamin B_{12} in foods. USDA Agr. Res. Serv. Home Econ. Res. Rept. 36. (Cited from R.S. Harris and E. Karmas, eds. 1975. Nutritional Evaluation of Food Processing. p. 238.)

40. Ournac, A. 1958. Evolution de la vitamin C dans le raisin conserve en frigorifique. Ann. Technol. Agr. 7:167-175. (Cited from M.A. Amerine, H.W. Berg and W.V. Cruess. 1972. The Technology of Wine Making. p.110).

41. Pavcek, P.L., and the Committee on Food Composition. 1946. Nutritive value of dehydrated vegetables and fruits. Ind. Eng. Chem. 38:853-855.

42. Pederson, C.S. 1971. Microbiology of Food Fermentation, The Avi Publishing Co., Westport, Conn.

43. Pederson, C.S. 1975. Pickles and sauerkraut. Pages 457-490. in B.S. Luh and J.G. Woodroof. Commercial Vegetable Processing. The Avi Publishing Co., Westport, Conn.

44. Pederson, C.S., Mack, G.W., and Athawes, W.L. 1939. Vitamin C content of sauerkraut. Food Res. 4:31-45.

45. Peynand, E., and Lafomacade, S. 1958. Evolution des vitamines B dans le raisin. Qual. Plant et Mat. Veg. 314,405-414. (Cited from M.A. Amerine, H.W. Berg, and W.V. Cruess. 1972. The Technology of Wine Making. p. 111.)

46. Proctor, B.E., and O'Meara, J.P. 1951. Effect of high-voltage cathode rays on ascorbic acid. Ind. Eng. Chem. 43:718-721.

47. Proctor, B.E., and Goldblith, S.A. 1949. Effect of soft X-Rays on vitamins (niacin, riboflavin and ascorbic acid). Nucleonics. 5(9); 56-62.

48. Raab, C.A., Luh, B.S., and Schweigert, B.S. 1973. Effects of heat processing on the retention of vitamin B_6 in lima beans. J. Food Sci. 38-544.

49. Ralls, J.W., Maagdenberg, H.J., Yacoub, N.L., and Mercer, W.A. 1972. Reduced waste generation by alternate vegetable blanching system. Proceedings of 3rd National Food Processing Waste Symposium, New Oreleans, La.

50. Ralls, J.W., Maagdenberg, H.J., Yacoub, N.L., Homnick, D., Zinnecker, M., and Mercer, W.A. 1973. In-plant, continuous hot-gas blanching of spinach. J. Food Sci. 38:192-194.

51. Retzer, J.L., Van Duyne, F.O., Chase, J.T., and Simpson, J.I. 1945. Effect of steam and hot-water blanching on ascorbic acid content of snap beans and cauliflower. Food Res. 10:518-524.

52. Salunkhe, D.K., 1974. Storage, Processing, and Nutritional Quality of Fruits and Vegetables. CRC Press, Ohio.

53. Schroeder, H.A. 1971. Losses of vitamins and trace minerals resulting from processing and preservation of foods. Am. J. Clin. Nutr. 24:562-567.

54. Stevens, H.P. 1943. Preliminary study of conditions affecting the nutritive values of dehydrated vegetables. J. Am. Dietet. Assoc. 19:832.

55. Thijssen, H.A.C. 1970. Freeze concentration of food liquids. Proc. 3rd Intern. Congr. Food Sci. Technol., pp. 491-498. (Cited from R.S. Harris and E. Karmas, eds. 1975. Nutritional Evaluation of Food Processing. p.323.)

56. Thomas, M.H., and Calloway, D.H. 1961. Nutritional value of dehydrated foods. J. Am. Dietet. Assoc. 39:105-116.

57. Tinklin, G.L., and Filinger, G.A. 1956. Effects of different methods of blanching on the quality of home frozen spinach. Food Technol. 10:198-201.

58. Tressler, D.K., Van Arsdel, W.B., and Copley, M.J. 1968. The Freezing Preservation of Foods. Vol.2: Factors affecting quality in frozen foods. The Avi Publishing Co., Westport, Conn. p. 343.

59. Tressler, D.K., Van Arsdel, W. B., and Copley, M.J. 1968. The Freezing Preservation of Foods. Vol.3: Commercial freezing of fresh foods. The Avi Publishing Co., Westport, Conn. p. 1.

60. Van Duyne, F.O., Wolfe, J.C., and Owen, R.F. 1950. Retention of riboflavin in vegetables preserved by freezing. Food Res. 15:53-61.

61. Watt, B.K., and Merrill, A.L. 1963. Composition of Foods. Handbook 8. Consumer Food Econ. Res. Div., ARS. USDA, Washington, D.C.

62. Woodroof, J.G., and Luh, B.S. 1975. Commercial Fruit Processing. The Avi Publishing Co., Westport, Conn.

63. Yoshida, T., and Hyodo, T. 1966. Superheated vapor speeds drying of foods. Food Eng. 38:86.

64. Zscheile, E.P., Beadle, B.W., and Kraybill, H.R. 1943. Carotene content of fresh and frozen green vegetables. Food Res. 8:299-313.

NUTRIENT CHANGES IN FRUITS AND VEGETABLES AFTER PROCESSING

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ABSTRACT

In human nutrition, vegetables and fruits contribute to supply vitamins and minerals as the main nutrients. Since minerals are rather stable to processing methods, vitamins are brought into focus of discussion in this paper.

The main purpose of processing is to apply different treatments to delay the deterioration of foods. When these treatments are employed, undesirable changes of food occur at the same time, one of which is nutrient losses. This study is to evaluate the effect of processing methods (thermal processing, moisture removal, freeze-preservation, fermentation, high sugar preservation and radiation treatment) on nutrient changes of fruits and vegetables, and to indicate how processing procedures may be altered to maximize the nutrient retention of the products.