Reprinted from the June, 1963, issue of ASHRAE Journal.



1970

# The Role of Temperature In Retaining Quality In Canned Foods

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The fact has been well established that all foods, whether they are sterilized, pasteurized, frozen, dehydrated, cured, or fresh, deteriorate in quality when held in storage. A report published in March, 1955, by the Office of the Quartermaster General Research and Development Division, "Establishing Optimum Conditions for Storage and Handling of Semi-Perishable Subsistence Items", presents data pertinent to this question in relation to canned foods, among other types of foods which were designated as "semi-perishable".

Canned foods are heat-treated. Heat-treatment can be either beneficial or harmful to foods. Where it is beneficial, improvement is exhibited usually in the food's organoleptic quality. Infrequently, heat denaturation of proteins results in improvement of nutritive quality of a food. Even those foods that are improved in food character by heating, however, suffer a reverse effect if the heating is prolonged. Not only is their nutritive value reduced but their tastiness and esthetic appeal are lessened.

The heat treatment required for sterilization of most low-acid foods (vegetables, dairy products, meat and seafoods), when applied in the conventional manner, has an effect which most people regard as an impairment of the organoleptic quality of the food and, in most instances, it also reduces the value of the food nutritionally. But, if we can develop a suitable method of heating the food rapidly to higher temperatures than those used in conventional processing and of cooling the food rapidly from that high temperature, we can sterilize the food while per-

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Fig. 1 HTST equipment used for laboratory scale production Chamber M and retort

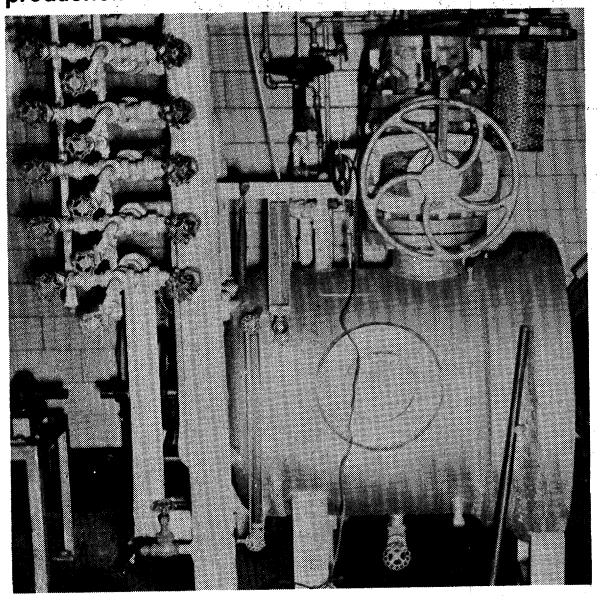
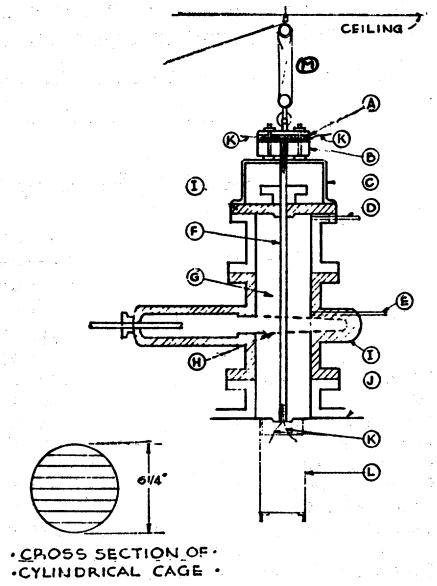


Fig. 2 Cross-section elevation of Chamber M

A. packing; B. 30 lb weight; C. girdle holding weight and packing; D. ⅝ in. pipe connection, water, steam, air, or vacuum; E. IBID; F. ⅜ in. stainless tube; G. Chamber M; H. 8 in. gate valve; I. wall of chamber M; J. retort wall; K. "thermocouples"; L. cylindrical cage for cans; M. block and tackle for raising and lowering basket L.



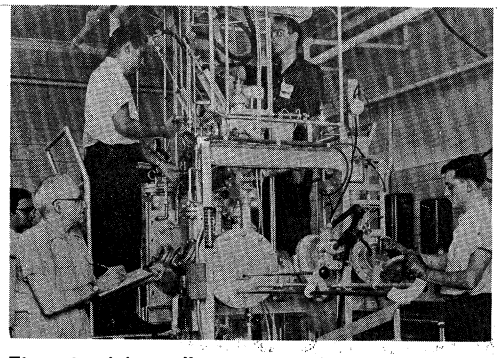


Fig. 3 Manually operated experimental machine capable of accomplishing ultra high temperature sterilization of either liqueform or particulate type foods

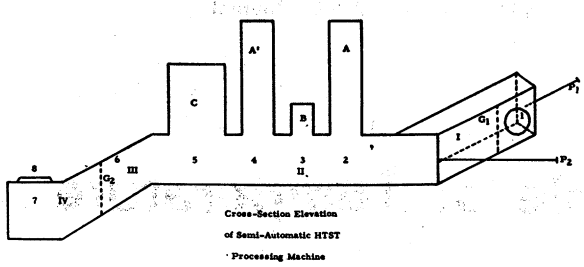



Fig. 4 Cross-section elevation of semi-automatic HTST processing machine

$P_1$. Push-rod, 1. Pressure tight door, $G_1$. Quick opening gate valve, I. Can entrance chamber, $P_2$. Push-rod, II. Main sterilizing and sealing chamber, A. Discrete particle heat exchanger, B. Sterilizing chamber for open can sterilization, A'. Discrete particle heat exchanger, 2. Filling position, 3. Can holding position for open can sterilization, 4. Filling position, 5. Sealing position, C. Can sealer and lid sterilizer, III. Holding leg, 6. Holding position, $G_2$. Quick opening gate valve, IV. Cooling, leg, 7. Position for can cooling, 8. Pressure tight door.

mitting it, largely, to retain its organoleptic and nutritive qualities.

This concept has been recognized by scientific and technical workers in the canning industry for nearly 40 yrs and, during this period, the concept of high-temperature-short-time (HTST) sterilization has come to be widely regarded as a means of improving the quality of canned foods.

Although one does accomplish sterilization of food while retaining much of its natural quality, the question immediately arises as to the practicability of doing this, because observation has seemed to indicate that the higher the quality of food when it goes into storage, the more rapidly that quality is lost during storage, so that the benefit gained by using an improved processing technique seems to be ephemeral. We feel that we have now disproved the validity of this observation, at least so far as its general applicability is concerned.

At Rutgers, a research project supported by the U.S. Public Health Service, The Refrigeration Research Foundation, and the U.S. Department of Agriculture, has studied these effects of processing technique and storage temperature upon the quality of vegetables, soups, baby food, and evaporated milk. The products, with the sterilizing process specifications for each, are listed in Table I.*

With the exception of evaporated milk, the conventional process of every product was conducted by a standard still-retort procedure with a come-up time of 3 min. Evaporated milk in one run was processed in a continuous cooker with standard procedure, including a 20-min preheat treatment, in the other run, in a laboratory retort with end-over-end rotation of the cans at 12 rpm and a preheat time of 15 min.

The HTST processing procedure was carried out with the equipment shown in Figs. 1 and 2. With equipment of a different type, which is now available, shown in Figs. 3 and 4, the processing time can be further reduced, producing sterile products of still higher quality than we have produced. Detailed descriptions of both types of equipment were published by Epstein, et. al.[3]

A sufficient amount of each of the products to give a complete complement of samples for all examinations, packed under vacuum in cans of the same size as those used in the conventional process, was frozen in air-blast at −50 F. These samples were stored at 0 F, while the processed samples were distributed equally among the temperatures of 25, 35, 50 and 85 F for storage. The schedule for examinations was 0, 3, 6, 12, 18 and 24 months after packing.

Two runs were made of each of the following products: evaporated milk, oyster stew, pea with ham soup, green beans, peas, and yellow-whole kernel corn and one run each of asparagus, vegetable beef soup, potato soup, shrimp soup, and tomato juice. Results presented herein are composite results of all studies of each product.

* Table I taken in part from Epstein, Arnold I., et. al.[3]

TABLE I Processing Specifications for HTST and Conventionally-Canned Products

| Product | Can Size Conventional Process | Processing Temp (F) HTST* | Processing Temp (F) Conv. | Length of Process HTST* (sec) | Length of Process Conv (min) | Cooling Time (min) HTST* | Cooling Time (min) Conv. |
|---|---|---|---|---|---|---|---|
| Green peas | 211 × 300 | 300 | 250 | 60-70 | 15 | 5 | 15 |
| Green beans | 211 × 300 | 300 | 245 | 50-60 | 15 | 5 | 15 |
| Asparagus | 211 × 300 | 300 | 240 | 65 | 27 | 5 | 15 |
| Whole kernel corn | 307 × 409 | 300 | 245 | 66-80 | 40 | 5 | 15 |
| Tomato juice | 307 × 409 | 300 | 212 | 60 | 25 | 2 | 15 |
| Evaporated milk | 300 × 306.5 | 300 | 243-242 | 75 | 16-20 | 2 | 15 |
| Oyster stew | 211 × 300 | 300 | 245 | 85-100 | 20-40 | 2 | 15 |
| Green pea with ham soup | 211 × 300 | 300 | 245 | 75-105 | 53 | 2 | 10 |
| Cream of shrimp soup | 211 × 300 | 300 | 245 | 130 | 53 | 2 | 10 |
| Cream of potato soup | 211 × 300 | 300 | 245 | 180 | 53 | 2 | 10 |
| Vegetable beef soup | 211 × 300 | 300 | 245 | 110 | 53 | 2 | 10 |
| Plum-tapioca baby food | 211 × 300 | 300 | 212 | 40 | 28 | 2 | 20 |
| Split pea with ham baby food | 211 × 300 | 300 | 245 | 110 | 60 | 2 | 20 |

* 211 × 011 cans were used in all HTST processes.

## RESULTS

### Color

Color measurements were made with a color difference meter in such a manner as to evaluate the attributes of hue and brightness. On the numerical scales used to express brightness and hue, degree of brightness varies directly as the value, that is, the higher the numerical value, the greater the degree of brightness, but there is no such regular relationship between hue and numerical value; this relationship depends upon the color of the object.

Both hue and brightness were more severely affected by conventional processing than by HTST processing or by freezing. Hue values were best maintained in frozen storage. Except in evaporated milk, brightness was retained better through the HTST process than through either the conventional or the freezing process.

### Hue

Hue is expressed as the angle on the color diagram of which the tangent is $a_L/b_L$. It takes its sign from the sign of its tangent. Inasmuch as the data of this project have yielded no negative values for $b_L$, all positive values of hue express ratios of red to yellow intensity and all negative values express ratios of green to yellow intensity.

In vegetables, the desirable greenness or yellowness at the time of entering storage generally was appreciably higher in the frozen samples than in the heat-sterilized samples. HTST processing was considerably better for retention of hue than conventional processing. Of the products studied, the following showed little effect of storage temperature upon hue: whole kernel yellow corn, tomato juice, shrimp soup and vegetable beef soup. Of the other products, composite hue values from all examinations for the products from different processes are given in Table II, with the number of examinations made on each product, and dumbbell symbols indicating significant differences in hue value at the 5% level*.

A major problem in interpreting data pertaining to the relationship between organoleptic properties of food and various factors that affect these properties is that of deciding how the significant facts best can be shown. It is desirable to show the relationships on as broad a base as possible, because thereby one lends strength to one's conclusions.

The data on hue will be interpreted in two ways to place emphasis on two different features. In the first, to which Table II applies, the results are based upon mean values of readings taken at from four to six different times; in the second, the individual readings are presented separately.

The first type (Type A) of interpretation, being based upon mean values for all readings, gives more authority to its indications than does the second type (Type B), which uses the values of single readings to

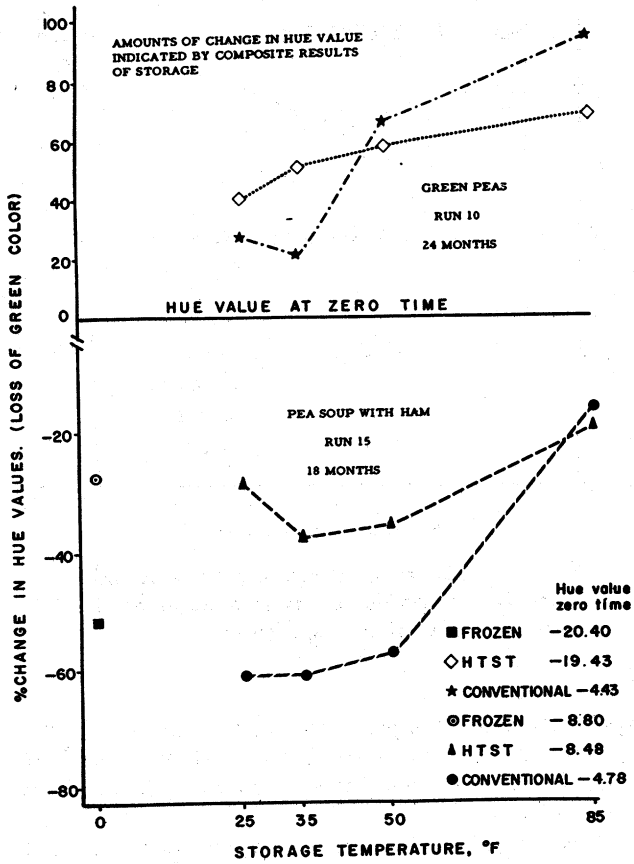



**Fig. 5 Amounts of change in hue value indicated by composite results of storage**

* Method of statistical analysis used: All sets of data were first analyzed by analysis of variance, then significant factors (treatments) in the results of the analysis of variance were analyzed by the method of multiple comparison of means described in "Applied Statistics for Engineers," by William Volk, McGraw-Hill Book Co., Inc., New York, 1958.

**TABLE II Composite Values of Hue Attributes of Color of Seven Products, for Different Processing Procedures, at Time of Entering Storage; also, Indication of Significant Differences at the 5% Level on Composite Results of All Examinations**

| | Green Peas | Signif Diff | Green Beans | Signif Diff | Asparagus | Signif Diff | Evap Milk | Signif Diff | Pea with Ham Soup | Signif Diff | Cream of Potato Soup | Signif Diff | Oyster Soup | Signif Diff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run | 10 | | 12 | | 20 | | 7 | | 15 | | 16 | | 4 | |
| Frozen | —20.40 | | —35.15 | | —10.9 | | — 1.80 | | —8.80 | | — 3.00 | | 7.70 | |
| HTST | —19.43 | | —19.00 | | — 3.9 | | — 2.08 | | —8.48 | | — 2.53 | | 7.35 | |
| Conventional | — 4.43 | | — 8.23 | | — 1.43 | | 10.22 | | —4.78 | | —15.73 | | 7.20 | |
| No. Examinations | 6 | | 5 | | 4 | | 6 | | 6 | | 6 | | 6 | |
| 25 F | | | | | | | | | | | | | | |
| 35 F | | | | | | | | | | | | | | |
| 50 F | | | | | | | | | | | | | | |
| 85 F | | | | | | | | | | | | | | |

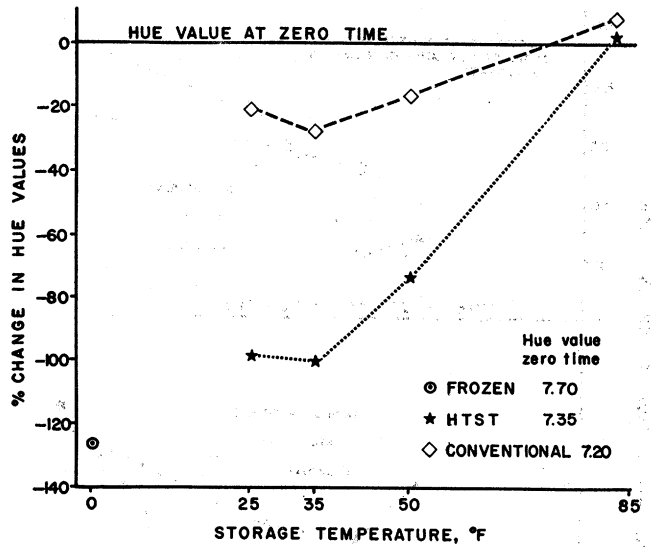



**Fig. 6 Amounts of change in hue value indicated by composite results of storage for 18 months. Oyster stew soup. Run 4**

express its relationships. Graphs are helpful in bringing out these points. Figs. 5 and 6 show what happened during storage to the hue of two of the products listed in Table II.

The negative hue values of green peas (run 10), green beans (run 12), asparagus, and pea with ham soup (run 15) signify green color of moderate intensity and yellow of high intensity on a scale in which zero represents zero green with maximum yellow and –90 represents maximum green with zero yellow. A value of –45 designates equal intensity of green and yellow. It is seen in Table II that, inasmuch as hue in a frozen product closely resembles that of the raw product, all of the green products lost some green color in the HTST process but lost much more in the conventional process.

### Peas and Pea Soup — Evaluation Type A for Hue

Fig. 5 shows that, in peas and pea soup, changes in hue during storage were in the direction of higher positive values or lower negative values for the higher storage temperatures, meaning that the intensity of green color decreased more rapidly at higher storage temperatures. Nevertheless, heat-processed pea soup at all storage temperatures, as well as frozen peas and pea soup, experienced a net increase in greenness during storage (hue became more negative) while heat-processed peas decreased in greenness (hue became less negative). HTST processed peas retained green color best at 25 F but conventionally processed peas and both HTST and conventionally-processed pea soup retained green color best at 35 F. In all instances, the products had less retention of green color at 50 than at 35 F and poorest retention at 85 F.

### Asparagus and Green Beans—Evaluation Type A for Hue

Conventionally-processed asparagus and both HTST- and conventionally-processed beans had best retention of green color at 25 F but HTST-processed asparagus had best retention at 35 F. In all cases except conventionally processed asparagus, the green color retention was poorer at 50 than at 35 F and, in all cases, the loss of greenness intensity was greatest at 85 F. This was especially pronounced in the conventionally-processed products.

Overall, heat-processed green beans, HTST-processed asparagus and frozen green beans had a net loss of green color (negative value of hue decreased) in storage at all temperatures, except green beans at 25 F. Conventionally-processed asparagus gained intensity of green color (hue became more negative) in storage at all temperatures, except 85 F. Frozen asparagus showed essentially no change in green intensity.

### Evaporated Milk and Potato Soup — Evaluation Type A for Hue

In both evaporated milk and potato soup the intensity of yellow color is much greater than that of either green or red color. In this scale, a hue value of zero signifies zero green or red color with maximum intensity of yellow color while a value of –90 signifies maximum intensity of green color and zero yellow and red color.

The general trend of change in hue value of evaporated milk and cream of potato soup seems to be that of increase downward (becoming either less positive or more negative) with increase in storage temperature. This trend is not, however, convincing since it applies definitely only to conventionally-processed evaporated milk and HTST-processed cream of potato soup. The observed trend indicates, for conventionally-processed evaporated milk, a reduction in redness and, for HTST-processed potato soup, an increase in greenness, both of which increased with increasing temperatures. There is no trend in relation to storage temperature in conventionally-processed cream of potato soup or in HTST-processed evaporated milk, although the former showed a major overall loss of green color. Insofar as the frozen products stored at 0 F are concerned, cream of potato soup showed a moderate reduction in negative hue value (loss of green color) during storage and evaporated milk a pronounced increase in negative value (gain in green color).

### Oyster Stew Soup — Evaluation Type A for Hue

Relationship between storage temperature and hue value change in oyster soup in run 4, is shown in Fig. 6. In this product, as shown in the legend on Fig. 4, process had little effect upon hue value but storage temperature had a major effect. Overall, the hue value decreased, indicating a loss of redness in all categories during storage except in the heat-processed products (HTST and conventional) stored at 85 F. The hue value of the frozen soup decreased in storage more than that of the heat-processed soup, in which the greatest decrease in hue value occurred at 35 F storage temperature, while, as stated above, there was practically no change in hue value in the soup stored at 85 F. What this means organoleptically is difficult to say. Chromatically, in this case, a hue value of zero is interpreted to signify zero red color and maximum intensity of yellow color, whereas, a hue value of 90 is said to signify zero yellow color and maximum intensity of red color. Thus, the lower temperatures

of storage had the effect of increasing the ratio of yellow intensity over red intensity. That is perhaps to the good in oyster soup.

A different approach (Type B) was used in interpreting the data on corn, which was one of the four products that showed no significant effects of storage temperature upon hue value. A similar analysis was made of green beans and evaporated milk. Only that on green beans is shown in Figs. 7 and 8 for comparison with the other system (hue value as such) which was applied to green beans (Fig. 2). The color differences in green beans produced by differences in storage temperature are among the most significant produced in canned vegetables by this factor. Conventionally-processed beans are omitted from Figs. 7 and 8.

In the Type B evaluation, the color components, $a_L$ and $b_L$, were kept separated instead of being combined to express hue value, and the readings after different periods of storage were kept separated instead of using the average values of these readings.

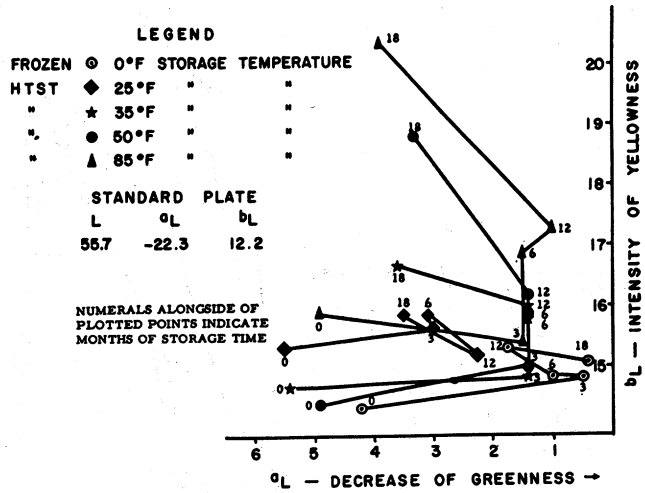



**Fig. 7 Amounts of change in hue value of frozen and HTST-processed green beans in run 12 indicated by results of storage for 18 months**

## Green Beans — Evaluation Type B for Hue

Study of hue in green beans from the standpoint of the separate components, $a_L$ and $b_L$, showed that storage temperature is a much more important factor from the standpoint of color in HTST-processed than in conventionally-processed beans. In both runs, 12 and 22, Figs. 7 and 8, respectively, all HTST-processed samples suffered losses of intensity of greenness which, at their maxima, varied between about 2 and 4 units on the $a_L$ scale. Perhaps more important, however, than the magnitude of the loss of greenness is the variation in the rates of loss. In run 12, most of the loss of greenness occurred during the first three months whereas, in run 22, only a small portion of the loss occurred during the first three months and loss continued in the beans at all storage temperatures for 18 months. This may indicate major genetic differences in raw material. In run 12, there was no loss between 3 and 6 months after packing but, later between 6 and 12 months, there was an additional loss, as measured by about 0.5 unit on the $a_L$ scale, in the beans stored at 25 and 85 F.

Another distinction between the two runs was that, in run 12, the product at all storage temperatures, during the period between 12 and 18 months after packing, regained approximately half of the intensity of greenness which they had lost, whereas, in run 22, the recovery was much less.

The point of greatest difference in respect to the HTST-processed beans between the two runs and among the different storage temperatures lies in the increase in intensity of yellowness (increase in value of the $b_L$ component on the Gardner Meter). In each run, the greatest increase in yellowness occurred in the samples stored at 85 F, which, in run 12, suffered an increase measured as 5 units on the $b_L$ scale and, in run 22, an increase twice as great. The increases in yellowness of the samples stored at the lower temperatures also were much greater in run 22 than in run 12. In each run, the principal effect of storage temperature upon color was exhibited in the increase in yellowness, which invariably increased with increase in storage temperature.

In the color differences shown among the samples of green beans stored at different temperatures, differences in yellowness generally predominated over differences in greenness. Table III clarifies these differences. In run 22 there were not sufficient samples of frozen beans for examinations after six months.

The data on conventionally-processed beans corresponding to those presented in Figs. 7 and 8 and Table III on HTST-processed beans are similar in nature to the latter but fall within different ranges

**TABLE III Greenness and Yellowness Values of HTST-Processed (25-, 35-, 50-, and 85-F Storage) and Frozen (0-F storage) Green Beans**

| Time (months storage) | Storage Temp (F) | RUN 12 Greenness* ($a_L$ Units) | RUN 12 Yellowness ($b_L$ Units) | RUN 22 Greenness* ($a_L$ Units) | RUN 22 Yellowness ($b_L$ Units) |
|---|---|---|---|---|---|
| 0 | 0 | 10.2 | 14.3 | 12.8 | 11.1 |
| | 25 | 5.5 | 15.3 | 4.1 | 11.3 |
| | 35 | 5.4 | 14.7 | 4.0 | 12.3 |
| | 50 | 4.9 | 14.4 | 4.6 | 12.9 |
| | 85 | 4.9 | 15.9 | 4.9 | 12.4 |
| 3 | 0 | 6.5 | 14.8 | 8.9 | 11.5 |
| | 25 | 3.0 | 15.6 | 3.3 | 12.5 |
| | 35 | 1.4 | 14.8 | 4.0 | 12.2 |
| | 50 | 1.4 | 14.9 | 4.3 | 13.5 |
| | 85 | 1.5 | 15.4 | 4.5 | 16.6 |
| 6 | 0 | 7.0 | 14.8 | 8.4 | 16.2 |
| | 25 | 3.1 | 15.9 | 2.8 | 12.5 |
| | 35 | 1.4 | 15.8 | 3.0 | 12.2 |
| | 50 | 1.4 | 15.9 | 3.8 | 14.0 |
| | 85 | 1.5 | 16.9 | 4.1 | 16.5 |
| 12 | 0 | 7.8 | 15.3 | — | — |
| | 25 | 2.3 | 15.2 | 2.7 | 14.8 |
| | 35 | 1.4 | 16.0 | 2.5 | 15.3 |
| | 50 | 1.4 | 16.2 | 2.7 | 17.4 |
| | 85 | 1.0 | 17.3 | 3.5 | 18.9 |
| 18 | 0 | 6.4 | 15.1 | — | — |
| | 25 | 3.5 | 15.8 | 1.0 | 18.3 |
| | 35 | 3.6 | 16.4 | 0.6 | 19.0 |
| | 50 | 3.3 | 18.8 | 0.7 | 20.0 |
| | 85 | 3.9 | 20.4 | 2.3 | 21.4 |
| 24 | 25 | | | 1.1 | 18.1 |
| | 35 | | | 1.2 | 18.5 |
| | 50 | | | 0.8 | 18.9 |
| | 85 | | | 3.7 | 20.0 |

* All $a_L$ values are negative. Minus signs are omitted in order to emphasize intensity of greenness.

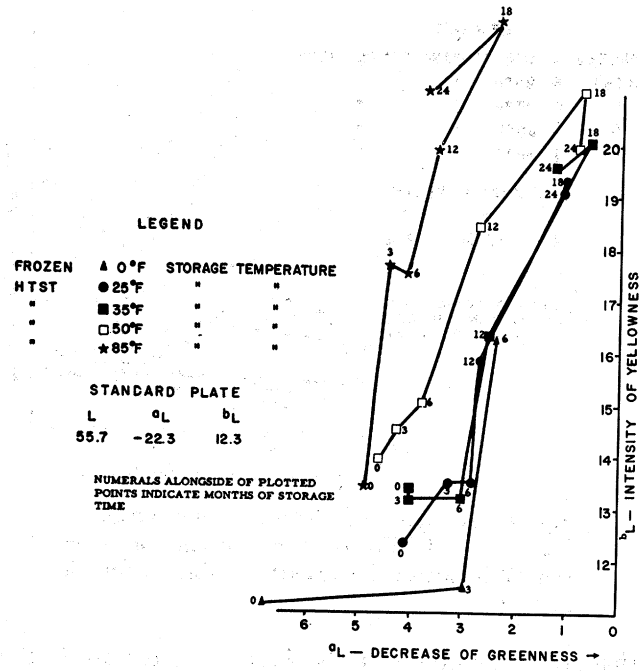



**Fig. 8 Amounts of change in hue value of frozen and HTST-processed green beans in run 22 indicated by results of storage for 24 months**

of greenness (see hue values, Table II) and have color changes which are generally of lower magnitude.

In Table III, it is seen that frozen beans, in run 12, had yellowness value close to that of HTST-processed beans and, in run 22, appeared to be heading for a higher yellowness value than that of HTST-processed beans. In both runs the greenness values of frozen beans were consistently much higher than those of HTST-processed samples.

### Yellow Whole Kernel Corn — Evaluation Type B for Hue

In intensity of yellow color ($b_L$ component on Gardner Meter) of HTST-processed corn, there was little distinction in favor of any storage temperature. A striking change, however, in yellow intensity occurred in run 23 between six and 12 months after packing when the samples stored at 85 F went from a low minimum to a high maximum value of yellowness. These samples maintained their superiority throughout the second year of storage. The same category of samples in run 13 experienced a similar change but of lower magnitude, between 18 and 24 months after packing. The most notable feature pertaining to yellowness of the conventionally-processed corn in runs 13 and 23 was an outstanding superiority of the corn stored at 25 F throughout the 2-year storage period.

The conventionally-processed samples also showed sharp changes in intensity of yellowness between 6 and 12 months after packing. The 35 and 50 F samples, in both runs 13 and 23, underwent a sharp increase and the 85 F samples in run 13 showed a sharp decrease in intensity of yellowness. After these changes, the relationship between storage temperature and yellowness in conventionally-processed corn in runs 13 and 23 was maintained during the second year with minimum value in 85 F samples and maximum value in 25 F samples.

Yellowness in frozen corn was practically equal to that of the HTST-processed corn and was significantly higher than that of the conventionally-processed samples.

### Evaporated Milk — Evaluation Type B for Hue

In both runs 7 and 19, hue of frozen evaporated milk decreased drastically during the first 6 months of storage, then increased, indicating that, during the first 6 months, the intensity of green color increased and that of yellow decreased. Huewise, the heat-processed products acted much differently. The HTST products in run 19, except those at 50 F storage, decreased in green color during the first 3 months, remained practically unchanged during the second three months, then increased, while in run 7, the milk in storage at all temperatures increased in green color during the first 6 months, then decreased. In both runs, the conventionally-processed products, except those in run 19, stored at 25 F, decreased in red color during the first 12 months of storage. In all heat-processed samples, the samples stored at 50 F generally had the lowest hue values (reduced red color, increased yellow color or increased green color and decreased yellow color). In the conventionally-processed products in run 7, the 50 F samples share minimum hue values with the 85 F samples.

Just what is the significance of a change in red color or in green color of evaporated milk is not apparent. It may be presumed, however, that red with yellow produces a browning of the product. A high intensity of yellow color was maintained throughout.

### Brightness

Brightness, being measurable as a single component by the Gardner meter, is expressible in simpler terms than is hue. Increase in numerical value directly signifies increase in brightness and vice versa. A study of our data on brightness, compiled on the procedure of computing mean values of all examinations in storage at a given temperature, led to a separation of our eleven products into four categories, the first of which, comprising green peas of run 10, pea soup of run 15, and tomato juice of run 11, having comparatively low initial (zero storage time) brightness values, within the range from 25 to 50, exhibited what were probably the most consistent relationships between brightness and storage temperature. Curves showing these relationships are shown in Fig. 9.

The patterns of change differ greatly among the three products. Heat-processed peas in storage increased in brightness approximately equally at all storage temperatures, although the increase was slightly greater in the HTST peas than in conventionally-processed peas. Brightness of heat-processed pea soup and tomato juice decreased in storage but not equally at all storage temperatures. Pea soup suffered its smallest reduction in brightness at 35 F and greatest reduction at 85 F while tomato juice suffered its smallest reduction in brightness at 85 F and its greatest reduction at 25 F. In both products, those that received the HTST process suffered less

reduction in brightness during storage than those that received the conventional process. Of the frozen products, peas and pea soup suffered loss of brightness during storage, whereas tomato juice increased in brightness. It is interesting to note that, in this respect, peas and tomato juice acted differently in frozen state than in sterilized state, whereas pea soup in both the frozen and heat processed forms lost brightness during storage.

The second group of products, consisting of asparagus, green beans, and yellow whole kernel corn, had initial brightness values within the medium range of from 32 to 63. These products showed less correlation between brightness and storage temperature than was found in the products of the first group. Another difference between the groups is a reversal of the relationship between HTST- and conventionally-processed products in respect to magnitude of brightness. Asparagus, green beans, and corn showed greater brightness in conventionally-processed than in HTST-processed products.

Brightness of heat processed green beans of run 12 and of yellow whole kernel corn of run 13 decreased in storage under all conditions except conventionally-processed green beans in storage at 50 and 85 F. In HTST-processed green beans, the greatest reduction in brightness occurred in storage at 25 F and there was progressively less reduction in brightness as storage temperature increased.

In noting a correlation between storage temperature and brightness of green beans, one is constrained to ponder the question as to just what sort of quality criterion brightness is.

In this case, it appears to correlate with yellowness. In both runs 12 and 22, the HTST-processed samples increased in brightness significantly and progressively as storage temperature increased from 25 to 85 F.

In conventionally-processed samples, run 22 showed no apparent effect of temperature upon brightness but run 12 showed some resemblance to that described for HTST beans.

In corn, there was little difference in loss of brightness at different storage temperatures except in conventionally-processed products stored at 85 F, which suffered substantial loss.

The effect of storage temperature on brightness of yellow whole kernel corn became strongly apparent among the conventionally-processed in runs 13 and 23 between 6 and 12 months after packing. Up to 9 months of storage, there was little distinction in brightness among samples of conventionally-processed corn stored at different temperatures and in HTST samples, this same situation prevailed practically through the entire storage period. Evident at one year and thereafter in the conventionally-processed samples was a rather wide separation among the samples stored at different temperatures. The 85 F samples showed minimum brightness and the 35 and 50 F samples showed maximum brightness. Brightness in frozen corn was lower than that in the HTST-processed corn but higher than that in the conventionally-processed corn.

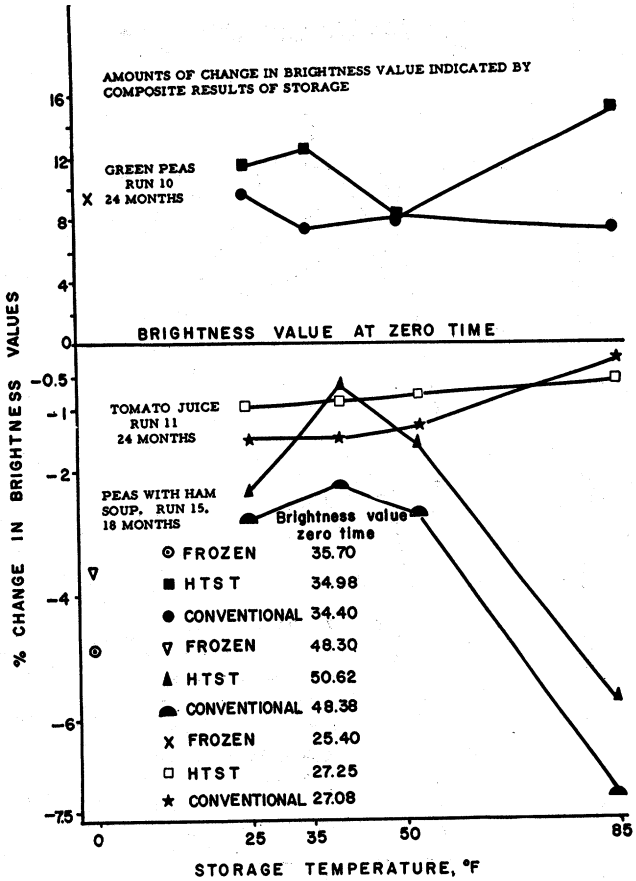



Fig. 9 Amounts of change in brightness value indicated by composite results of storage

Frozen green beans did not change in brightness during storage, while frozen corn suffered a moderate loss of brightness, about equal to the average suffered by the heat-processed corn.

Heat-processed asparagus exhibited an increase in brightness during storage in all conditions except in HTST-processed product stored at 25 and 85 F and conventionally-processed product at 25 F. An interesting feature is that the brightness of HTST-processed asparagus was maximum in storage at 35 F and that of conventionally-processed asparagus was maximum in storage at 50 F. The brightness of frozen asparagus increased substantially during storage at 0 F.

The third group of products comprised shrimp soup and vegetable beef soup, the initial brightness values of which varied from 44 to 65. Both heat-processed and frozen vegetable beef soup in run 5

TABLE IV Evaporated Milk (Run 7): Unadjusted Panel Score For Flavor Difference from Reference Standard

| Type of Process | Storage Temp (F) | Months in Storage 0 | 3 | 6 | 12 | 18 | 24 |
|---|---|---|---|---|---|---|---|
| Freezing ..... | 0 | 4.48 | 4.02 | 4.90 | 4.87 | 4.03 | 3.81 |
| Conventional Heat | 85 | 1.44 | 2.18 | 2.27 | 2.63 | 3.85 | 3.78 |

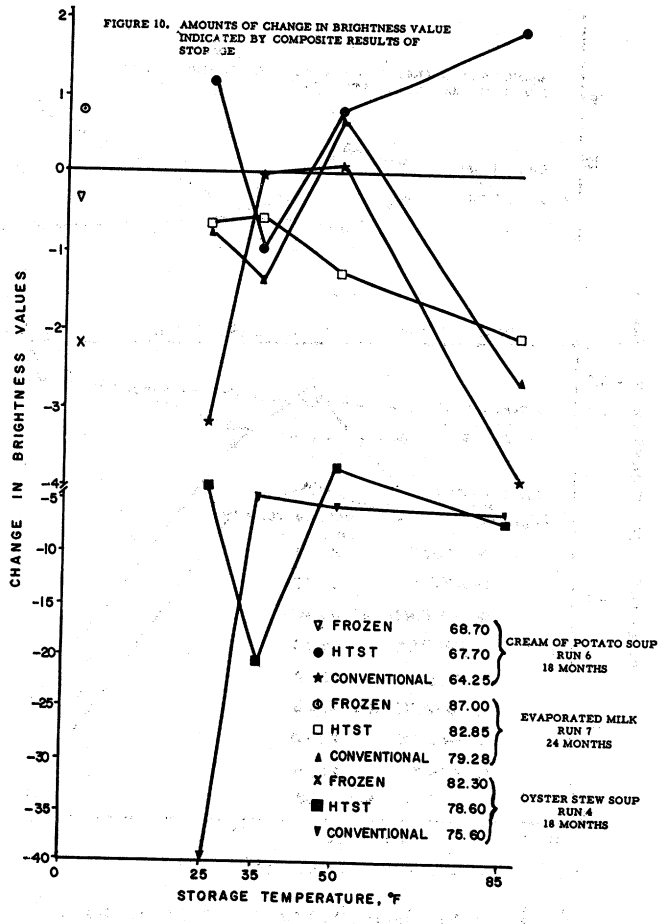



**Fig. 10 Amounts of change in brightness value indicated by composite results of storage**

suffered substantial loss of brightness during storage and both heat-processed and frozen shrimp soup, except for those lots of heat-processed product stored at 25 and 35 F, suffered moderate loss of brightness during storage in run 18. In both conventionally-processed products, there was a fair degree of consistency within each product in the relationship between change in brightness and storage temperature but the direction of the relationship was reversed in one product in respect to the other.

The fourth and final group of products consisted of evaporated milk, cream of potato soup, and oyster soup, of which the initial brightness values varied within the high range from 64 to 87. There was nothing regular or consistent in their relationship between change of brightness and storage temperature, as shown by the curves in Fig. 10.

In both runs, 7 and 19, in conventionally-processed evaporated milk, brightness was lowest at 85 F storage and, in each run, maximum brightness was divided between 35 and 50 F. In HTST-processed milk, the 85 F product shared minimum brightness with the 25 F product in run 19 and with the 50 F product in run 7. Maximum brightness was shared by the 35 F product in run 7 with the 25 F product and in run 19 with the 50 F product.

These data seem to show that heat-processed products having brightness values in the lower part of the range of from 30 to 90 in the Gardner scale tend to exhibit a degree of regularity and consistency in their relationships between temperature of storage and change of brightness value in storage which is not exhibited by products having brightness values in the upper part of the range of from 30 to 90. This regularity and consistency, however, does not extend to the matter of whether there is an increase or a decrease in brightness value during storage. In other words, some products having low initial brightness value may exhibit an increase in brightness, and others may exhibit a decrease in brightness during storage. Those having high initial brightness value seem to be prone to suffer a decrease in brightness during storage.

## FLAVOR

Flavor evaluations in terms of flavor difference and flavor preference were based upon the expression of a 20-member flavor panel. Difference from a labeled reference standard was rated on a nine-point numerical scale, with the following designations: 1. no difference; 3. slight; 5. moderate; 7. large; and 9. extreme difference. Preference was expressed in terms of better than, comparable to, or poorer than the reference standard.

The reference standard was given the conventional process and was stored at 35 F. The numerical scale value of a test sample having the same specifications as the reference standard served as a base line score for a series of test samples and thus was used as a calibration of the taste panel. A mean panel score (average for all judges) of 1.0 in an examination of such a test sample indicated perfect performance by the panel for that examination of the product. Unless the rating of this test sample by an individual judge fell within prescribed limits, that judge's results on the series of samples involved were excluded from the panel score.

The interpretation of the data will be illustrated by an example. Using evaporated milk of run No. 7, the average score values of panel members, unadjusted for panel error except for discarding glaringly erroneous individual scores, for difference in flavor

**TABLE V Evaporated Milk - Run 7; Total Difference and Net Predominance in Respect to Preference in Terms of Per cent in Total Difference**

| Type of Process | Storage Temp (F) | Readings for Zero Time 3 mos. and 6 mos. Total Points | Per cent Better | Per cent Comp. | Per cent Poorer | All Readings Total Points | Per cent Better | Per cent Comparable | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 13.40 | 19.5 | — | | 26.11 | 5.4 | — | |
| Conventional | 35 | 3.51 (3.00) | | | | 7.02 (6.00) | | | |
| Conventional | 85 | 5.89 | | — | 16.9 | 16.15 | | — | 43.2 |

from the reference standard, are shown in Table IV for frozen samples stored at 0 F and conventionally-processed samples stored at 85 F.

Totals were taken of the values of all six periodic readings shown in Table IV for each category; also for the first three periodic readings, viz., zero time, three months, and six months, for each category. For the frozen samples, these totals were 26.11 and 13.40, respectively, and for the conventionally-processed samples, 16.15 and 5.89, respectively. These are shown in Table V with the panel ratings for conventional samples stored at 35 F to indicate the degree of panel error (see "Calibration of Panel"). The net number of the points of each designation indicating a predominance of opinion of (1) better than the reference, (2) comparable to the reference, or (3) poorer than the reference was then calculated in terms of percentage of the total number of points in each designation. The grading procedure was as follows: if, in one evaluation of a product, preference ratings of individual panel members were distributed among all categories, viz., better than, comparable to and poorer than the reference and if "better than" and "poorer than" cancelled each other, the panel score was classified as representing a preference of "comparable to" with a percentage rating equal to 100 times the fraction of the panel members who voted "comparable to." If grades of "better than" and "poorer than" were both zero, the grade was 100% comparable. If "better than" and "poorer than" did not cancel each other, the points labelled "comparable to" were dropped and the difference in points between "better than" and "poorer than", converted to per cent of total, was taken as the grade.

For example, any total number of points representing only one classification of preference was shown as 100 per cent in that classification. If a total of 25 points was distributed 10 points each to "better than" and "comparable to" and 5 points to "poorer than", the grade was 20 per cent better than, which is represented by the 5 points difference between "better than" and "poorer than", expressed as percentage of all points. For the example of evaporated milk in run 7, the results are shown in Table V.

Thus, the flavor evaluation for evaporated milk in run 7 indicated that, during the first six months of storage, the frozen milk had substantially better flavor than the reference (19.5% net) while over the 24-month period, it was only slightly better (5.4% net) than the reference. On the other hand, during the first six months, the conventionally-processed milk stored at 85 F was somewhat poorer in flavor (16.9% net) than the reference, while, over the 24-month period, it was very much poorer than the reference (43.2% net). It is emphasized that these values are derived through an arbitrary evaluation procedure which bears no direct relationship to any statistical analysis.

The results of the evaluation of 10 items, selected as will be described, corresponding to the results in Table V for the evaporated milk example, are given in Tables VI-A to VI-J, inclusive. In only a part of the runs are results shown for storage over the entire period of 24 months. These are peas run 10, potato soup run 16, evaporated milk run 19, shrimp soup run 18, yellow whole kernel corn runs 13 and 23, vegetable beef soup run 5, and a portion of the oyster stew run 17 samples. For each of the other runs, the total number of examinations is shown in the table by a numeral in parentheses following the total points for all readings on the HTST-processed product stored at 25 F. For each of the products, the total number of examinations of the frozen samples is shown in the table by a numeral in parentheses following the total points for all readings on the frozen products. Some frozen samples were lost because of storage cabinet failure. Also, panel preference ratings are shown in brackets for the final examination of each

**TABLE VI-A* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance in Respect to Preference in Terms of Per Cent of Total Difference**

**OYSTER STEW - RUN 17**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 14.31 | 24.7 [12.9]** | | | 18.33 (4) | 9.4 | | [25.0 ]** |
| HTST | 25 | 12.17 | 37.8 [50.0] | | | 23.19 (6) | 20.5 | | [24.3 ]** |
| | 35 | 11.64 | 28.0 [34.4] | | | 22.75 (6) | 5.4 | | [ 5.7 ] |
| | 50 | 11.65 | 40.0 [45.4] | | | 18.25 (5) | 6.8 | | [15.1 ]** |
| | 85 | 11.60 | 23.2 [30.3] | | | 19.41 (5) | 8.1 | | [50.0 ] |
| Conven. | 25 | 4.00 | | [100] | 2.5 | 9.74 (6) | | | 10.3 [37.8 ] |
| | 35 | 3.21 (3.00) | | [100] | 1.2 | 7.36 (6.00) | | [94.5 ] | 0.6 |
| | 50 | 4.25 | | | 3.7 [ 3.2] | 9.11 (5) | | | 3.5 [ 9.1 ] |
| | 85 | 5.40 | | | 16.9 [27.3] | 11.63 (5) | | | 21.8 [92.3 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the period 6 months (3rd exam.), 12 months (4th exam.), 18 months (5th exam.), or 24 months (6th exam.).

**TABLE VI-B* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance in Respect to Preference in Terms of Per Cent of Total Difference**

**PEA WITH HAM SOUP; RUN 15**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 6.21 (2) | | | 7.4 | 12.61 (4) | | | 0.9 |
| | | | | [30.8]** | | | | | [ 4.4 ]** |
| HTST | 25 | 6.48 (2) | 14.8 | | | 18.10 (5) | 15.4 | | |
| | | | | | [ 7.7] | | [33.3]** | | |
| | 35 | 6.46 (2) | 18.5 | | | 17.90 | 12.7 | | |
| | | | [ 7.7] | | | | | [18.5] | |
| | 50 | 6.59 (2) | 19.6 | | | 17.52 (5) | 9.1 | | |
| | | | [15.4] | | | | [21.4] | | |
| | 85 | 5.76 (2) | 18.2 | | | 17.13 (5) | 1.4 | | |
| | | | | | [ 7.7] | | | | [32.2 ] |
| Conven. | 25 | 3.47 (2) | 3.7 | | | 8.98 (5) | 2.9 | | |
| | | | | | [ 3.6] | | | | [14.8 ] |
| | 35 | 2.20 (2.00) | | 100 | | 6.01 (5.00) | 2.1 | | |
| | | | | [100] | | | [ 7.4] | | |
| | 50 | 3.77 (2) | | | 9.4 | 9.08 (5) | 4.2 | | |
| | | | | | [ 7.8] | | [ 3.0] | | |
| | 85 | 4.18 (2) | | | 19.6 | 11.06 (5) | | | 24.5 |
| | | | | | [36.0] | | | | [33.4 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods 3 months (2nd exam.), 18 months (4th exam.), or 24 months (5th exam.). Examination at 6 months was not made.

period, viz., 6 months' examination for all samples, 12 or 18 months' examination for frozen samples, and 24 months' examination for heat-processed samples.

### Calibration of Panel

Numbers are also shown in parentheses in Tables VI-A to VI-J following the total difference figures for conventionally-processed products stored at 35 F which are the panel's ratings for difference between the reference standard and the coded reference standard. The numerals in parentheses are the numbers of points difference from the labeled reference standard which would represent perfect performance by the panel. Considering arbitrarily that one point of error in the panel's rating for this difference in each examination (three points total for three examinations) would represent an error of 100 per cent, we find that the percentages of error by the panel in the examinations of the samples in all runs were as given in Table VII.

In this evaluation, it was arbitrarily decided that when a panel error for overall performance on a product is greater than 10%, the results should be questioned and when the error is as great as 15%, the results are entitled to little confidence. On this basis, for the purpose of this evaluation, the flavor results of all runs except 15, 16, 17, 19, 5, 18, and 10 were discarded. The results of the first four accepted runs were accepted with a good deal of confidence, the results of the other three runs, with a degree of cau-

**TABLE VI-C* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance in Respect to Preference in Terms of Per Cent of Total Difference**

**POTATO SOUP; RUN 16**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 12.10 (3) | 23.2 | | | 15.99 (4) | 9.2 | | |
| | | | [25.0]** | | | | | | [15.4 ]** |
| UHT | 25 | 11.23 | 31.0 | | | 24.55 (6) | 11.5 | | |
| | | | [41.0] | | | | | | [48.5 ] |
| | 35 | 12.15 | 22.5 | | | 24.66 | 3.7 | | |
| | | | [ 5.9] | | | | | | [48.5 ] |
| | 50 | 12.94 | 18.0 | | | 25.54 | 8.7 | | |
| | | | [13.3] | | | | | | [39.4 ] |
| | 85 | 11.93 | 20.6 | | | 25.65 | | | 2.5 |
| | | | [13.3] | | | | | | [45.4 ] |
| Conven. | 25 | 4.20 | | | 4.3 | 10.72 | | | 13.7 |
| | | | [12.5] | | | | | | [ 3.0 ] |
| | 35 | 3.18 (3.00) | | 89.1 | | 6.83 (6.00) | | | 0.6 |
| | | | | [100.0] | | | | 100.0 | |
| | 50 | 4.24 | | 85.6 | | 9.84 | | | 7.5 |
| | | | | | [ 6.2] | | | | [14.7 ] |
| | 85 | 5.77 | | | 20.3 | 14.89 | | | 34.2 |
| | | | | | [33.0] | | | | [66.6 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the period (6, 12, or 24 months).

**TABLE VI-D* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

**EVAPORATED MILK; RUN 19**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 12.18 (3) | 1.3 [ 2.6]** | | | 14.85 (4) | 7.9 [ 7.9]** | | |
| UHT | 25 | 8.48 | 16.2 [ 5.5] | | | 20.15 (6) | | | 18.4 [44.7 ]** |
| | 35 | 8.51 | 17.6 [ 2.7] | | | 17.58 | 3.5 | | [ 2.6 ] |
| | 50 | 6.78 | 18.2 [13.9] | | | 16.62 | | | 0.6 [44.4 ] |
| | 85 | 9.12 | | | 20.5 [41.6] | 20.43 | | | 36.1 [61.1 ] |
| Conven. | 25 | 4.55 | 2.6 [ 2.6] | | | 11.55 | | | 8.0 [ 2.8 ] |
| | 35 | 3.21 (3.00) | 1.3 | [100.0] | | 7.32 (6.00) | | 100.0 [100.0] | |
| | 50 | 3.87 | | 86.7 | [ 2.6] | 10.15 | 9.8 | | [13.9 ] |
| | 85 | 6.78 | | | 23.0 [30.5] | 17.28 | | | 40.0 [61.1 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6, 12, or 24 months).

tion. The evaluations of runs 17, 15, 16, and 19 are shown in Tables VI-A to VI-D, and of runs 5, 18, and 10 in Tables VI-E to VI-G, inclusive.

Oyster Stew, Run 17. (Table VI-A) Until very late in the storage period, both the frozen and the HTST samples, stored at all temperatures, were rated superior to the reference standard. All were substantially different from the reference with the greatest difference after both six months and 12 months being shown by the frozen samples. During the first six months of storage, there was no significant difference due to storage temperature shown by the HTST samples although the lowest preference was shown for the samples stored at 85 F. In the conventionally-processed samples, the difference due to storage temperature was not significant although the preference was substantially less for the samples stored at 85 F than for the samples stored at refrigeration temperature.

Pea with Ham Soup, Run 15. (Table VI-B) There was no examination of this product six months after packing. At three months (second examination) preference was shown for HTST-processed samples at all storage temperatures over either frozen or conventionally-processed samples. Up through 24 months (5th examination) the HTST samples stored at 25, 35, and 50 F were preferred over all others. At the 3-months' examination, all samples stored at 25 F and 85 F had passed into a lower preference rating than the samples stored at 35 and 50 F. This relationship

**TABLE VI-E* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

**VEGETABLE BEEF SOUP; RUN 5**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 6.85 | | | 23.5 [25.0]** | 16.20 (6) | | | 18.0 [ 3.23]** |
| HTST | 25 | 6.51 | | | 23.9 [21.1] | 16.21 | | | 18.5 [19.4 ] |
| | 35 | 7.25 | | | 44.1 [26.4] | 17.75 | | | 30.6 [32.3 ] |
| | 50 | 8.43 | | | 26.0 [19.1] | 18.26 | | | 28.0 [47.0 ] |
| | 85 | 8.83 | | | 55.5 [23.8] | 20.20 | | | 61.2 [76.5 ] |
| Conven. | 25 | 4.12 | | | 6.4 [20.0] | 9.47 | | | 5.0 [ 9.7 ] |
| | 35 | 3.39 (3.00) | | | 4.2 [ 4.8] | 6.78 (6.00) | | [100] | 1.3 |
| | 50 | 5.18 | | | 11.8 [15.0] | 10.96 | | | 11.8 [29.4 ] |
| | 85 | 4.07 | | | 9.1 [21.1] | 11.43 | | | 18.8 [44.1 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6 or 24 months).

**TABLE VI-F* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

**SHRIMP SOUP; RUN 18**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 9.04 | | | 14.8 [ 2.7]** | 11.78 (4) | [5.0]** | | 8.3 |
| HTST | 25 | 9.10 | 6.4 | | [13.5] | 20.46 (6) | | | 13.4 [32.3 ]* |
| | 35 | 9.26 | 3.8 | | [21.6] | 21.15 | | | 27.5 [76.4 ] |
| | 50 | 0.75 | 6.6 | | [16.6] | 19.90 | | | 29.9 [59.4 ] |
| | 85 | 10.33 | | 21.0 | [22.2] | 23.86 | | | 37.7 [90.6 ] |
| Conven. | 25 | 4.51 | [2.6] | 84.2 | | 11.11 | | | 1.1 [18.9 ] |
| | 35 | 3.42 (3.00) | [2.7] | | 1.3 | 7.94 (6.00) | | [100] | 0.6 |
| | 50 | 5.23 | | | 3.9 [10.8] | 11.65 | | | 9.5 [37.8 ] |
| | 85 | 6.32 | | | 21.1 [11.1] | 15.86 | | | 36.7 [43.7 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6, 12, or 24 months).

continued throughout the storage period except that the HTST 25 F samples gave evidence of improving in quality during storage after 6 months. For the conventionally-processed samples, the results can be described in essentially the same terms as those for oyster stew in run 17.

Potato Soup, Run 16 (Table VI-C). Through 24 months, there was little basis for choosing any one from among the HTST samples stored at all temperatures and the frozen samples except that highest preference was shown for HTST samples stored at 25 F and lowest preference for samples stored at 85 F. In the conventionally processed samples, the difference was significantly greater than in the HTST samples and the preference was substantially less for the samples stored at 85 F than for samples stored at refrigeration temperature.

Evaporated Milk, Run 19 (Table VI-D). Through both 6 months (3 examinations) and 24 months (6 examinations), HTST samples stored at 35 and 50 F and frozen samples were preferred over other samples. HTST samples stored at 85 F, after both periods, were definitely inferior to the other samples and, in the longer period, these were joined in the inferior category by HTST samples stored at 25 F, although, through the six-month period, the latter samples were still superior. The picture for the conventional samples was almost identical to that for potato soup except that the "poorer" rating of samples stored at 85 F was greater for milk than for potato soup. Al-

**TABLE VI-G* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

**PEAS; RUN 10**

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 13.31 | 14.3 [50.0]** | | | 22.15 (5) | 4.6 | | [20.7 ]** |
| UHT | 25 | 10.69 | 27.0 [46.4] | | | 19.32 (6) | 6.8 | | [20.0 ]** |
| | 35 | 9.75 | 11.1 [14.3] | | | 19.14 | | | 8.3 [15.0 ] |
| | 50 | 8.87 | 17.5 [21.4] | | | 17.15 | | | 8.3 [28.5 ] |
| | 85 | 8.74 | | | 15.6 [ 7.1] | 18.91 | | | 30.2 [76.2 ] |
| Conven. | 25 | 4.39 | | | 7.9 [25.0] | 10.81 | | [ 68.5] | 9.5 |
| | 35 | 3.33 (3.00) | | 92.0 [100.0] | | 6.66 (6.00) | | 95.0 [100.0] | |
| | 50 | 5.2 | 7.9 | | [ 7.1] | 10.93 | 2.9 | | [21.0 ] |
| | 85 | 5.61 | | | 11.1 [17.8] | 12.38 | | | 22.2 [38.1 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6, 18, or 24 months).

though the differences between the reference standard and the conventional 85 F samples were less than those between the reference standard and the HTST 85 F samples, the "poorer" rating was higher for the conventional than for the HTST samples.

Vegetable Beef Soup, Run 5. (Table VI-E) Through both six months and 24 months, both the frozen and all HTST samples were rated as poorer than the reference standard. Among the HTST samples, the difference ratings applying to both storage periods (6 months and 24 months) increase consistently with increasing storage temperature between 25 and 85 F but the "per cent poorer" ratings showed no such consistent variation. The conventional samples were all indicated as somewhat poorer than the reference standard through the 6-months period but through the 24-months period, except for the 25 F samples, there was consistently increasing "poorer" rating with increasing storage temperature.

Shrimp Soup, Run 18 (Table VI-F). Through 3 months, all HTST samples were rated either better than or comparable to the reference standard. Through the 6-months period, there was a progressive slight increase in difference rating among the frozen and HTST samples with frozen samples having the smallest difference (9.04) and with difference for HTST samples increasing from that value with increase of storage temperature. Preference ratings, however, at the 6-months examination did not correlate directly with the difference ratings. These indicated lowest flavor quality in the 85 F HTST samples (22.2% poorer), next lowest (21.6% poorer) in the 35 F HTST samples, and highest (2.7% poorer) in the frozen samples. Through 24 months, all samples except the conventionally-processed samples stored at 35 F were rated inferior to the reference standard. The conventional samples show the typical pattern of oyster stew in run 17.

Peas, Run 10 (Table VI-G). Among the frozen and HTST samples in both the 6-months and the longer periods, the frozen samples had the highest difference ratings and they were only slightly superior in flavor to the reference standard. Through the 24-months' period, all HTST except the 25 F samples were rated inferior to the reference but, through the 6-months period, the samples stored at 25, 35, and 50 F were rated decidedly superior in flavor to the reference standard. Through both storage periods, the 85 F HTST samples were strongly inferior compared to other HTST and frozen samples. The conventionally-processed samples presented a picture with similar characteristics to that of the potato soup.

### Effects of Erroneous Performance by Panel

Even in the instances in which the panel calibration showed erroneous performance to the extent of 15% or more, samples stored at 85 F were consistently rated to have inferior flavor, as they were in practically all other runs. Aside from that uniformity of characteristic among all runs, the ratings for each of the runs having the highest panel-performance errors showed a tendency to monotony of patterns within itself — either in the direction of "better than" or in that of "poorer than" the reference standard for the product, regardless of processing method and storage temperature.

### Discussion of Flavor

The panel experienced its greatest performance difficulty in tasting non-formulated foods, specifically, the vegetables. In eight flavor evaluation programs on five vegetables, only one was made on a performance error of less than 15%. This was one of the two programs carried out on green peas. Soups appeared to offer considerably less difficulty to the panel. Five out of seven programs were completed with a performance error of less than 15%, although the third

**TABLE VI-H* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

OYSTER STEW; RUN 4
(high panel error)

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 8.12 | [5.9]** | | 2.7 | 15.61 (5) | [12.1]** | | 3.8 |
| HTST | 25 | 10.43 | | | 50.3 [50.0] | 17.21 (5) | | | 35.3 [12.6 ] |
| | 35 | 9.64 | | | 49.3 [27.8] | 16.57 | [ 2.9] | | 25.2 |
| | 50 | 9.06 | | | 42.7 [52.7] | 16.01 | | | 29.3 [23.5 ] |
| | 85 | 10.28 | | 25.0 | [68.3] | 19.46 | | | 40.4 [74.3 ] |
| Conven. | 25 | 3.76 | | | 5.3 | 8.15 | | | 2.2 [ 3.0 ] |
| | 35 | 3.69 (3.00) | [5.9] 8.0 | | | 6.15 (5.00) | 4.4 | | [ 2.9 ] |
| | 50 | 4.04 | [5.3] 6.9 | [ 88.1] | | 7.60 | 2.3 | 100 | [ 6.1 ] |
| | 85 | 6.98 | [5.6] | | 18.7 | 14.79 | | | 42.3 [61.8 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6 or 24 months). No examination at 18 months.

highest panel performance error (Table VII) occurred on oyster soup run 4.

Regardless of the magnitude of the performance error, the flavor evaluation programs almost invariably showed a much greater deterioration of flavor in samples stored at 85 F than in those stored at 50 F. To illustrate this, the data on the two products, oyster stew run 4 and yellow whole kernel corn run 23, runs in the group on which the greatest panel errors occurred, are shown in Tables VI-H and VI-I, respectively. Somewhat surprisingly, this difference at times (example, corn run 13) was more striking in conventionally-processed than in HTST-processed foods. This showing may have been the result of performance error.

The differences between 25, 35 and 50 F, in effects upon flavor of the canned foods tested, were not striking. In certain instances, notably conventionally-processed evaporated milk, peas, pea soup, potato soup, shrimp soup, tomato juice, green beans, corn, and asparagus, the HTST-processed evaporated milk and green beans, the flavor of samples stored at 25 F was rated inferior to that of samples stored at 35 F. This relationship is shown in conventionally-processed yellow whole kernel corn run 13 in Table VI-J.

Whole Kernel Corn, Run 13 (Table VI-J). The

**TABLE VI-I* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

YELLOW WHOLE KERNEL CORN; RUN 23
(high panel error)

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 11.24 | 8.3 [10.5]** | | | 11.24 (3) | 8.3 [10.5]** | | |
| HTST | 25 | 10.12 | 13.6 [15.8] | | | 20.59 (6) | 1.7 [18.2] | | |
| | 35 | 9.76 | 19.3 [15.8] | | | 22.06 | | | 10.2 [25.0 ] |
| | 50 | 9.64 | 16.7 [10.8] | | | 21.57 | | | 22.6 [16.6 ] |
| | 85 | 10.56 | | | 23.3 [37.9] | 25.52 | | | 52.2 [71.0 ] |
| Conven. | 25 | 4.99 | | 90.5 | | 12.64 | | | 2.2 [12.9 ] |
| | 35 | 3.90 (3.00) | | 100 [100] | [ 2.6] | 7.80 (6.00) | | 97.9 [ 88.5] | |
| | 50 | 5.75 | | | 8.3 [10.5] | 13.14 | | | 22.4 [61.3 ] |
| | 85 | 5.92 | | | 10.5 [16.2] | 17.44 | | | 31.5 [45.2 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6 or 24 months).

**TABLE VI-J* Flavor Evaluation; (1) Total Mean Difference from the Reference Standard and (2) Net Predominance In Respect to Preference in Terms of Per Cent of Total Difference**

YELLOW WHOLE KERNEL CORN; RUN 13
(greatest panel error)

| Type of Process | Storage Temp (F) | Zero Time, 3 mos., 6 mos. Total Diff | Per cent Better | Per cent Comp | Per cent Poorer | All Readings Total Diff | Per cent Better | Per cent Comp | Per cent Poorer |
|---|---|---|---|---|---|---|---|---|---|
| Freezing | 0 | 13.64 | 8.6 [ 3.7]** | | | 21.66 (5) | | | 5.2 [20.5 ]** |
| UHT | 25 | 11.61 | | | 26.8 [ 7.1] | 23.24 (6) | | | 33.8 [51.6 ]** |
| | 35 | 11.90 | 5.8 [14.3] | | | 23.72 | | | 20.8 [ 6.5 ] |
| | 50 | 12.33 | | | 8.6 [18.5] | 23.68 | | | 28.4 [59.3 ] |
| | 85 | 11.77 | | | 16.0 | 23.42 | | | 30.0 [33.1 ] |
| Conven. | 25 | 8.06 | [ 7.7] | | 19.7 [22.2] | 14.92 | | | 21.6 [11.1 ] |
| | 35 | 4.59 (3.00) | 1.3 | [100] | | 9.18 (6.00) | 1.1 | [100] | |
| | 50 | 7.83 | | | 7.4 [14.8] | 13.55 | | | 10.0 [11.4 ] |
| | 85 | 8.37 | | | 32.4 [37.0] | 20.11 | | | 43.2 [59.4 ] |

* A portion of these data is presented elsewhere in other form by Joffe, et al (4, 5).
** Values within brackets are panel preference ratings in the final examinations of the periods (6, 18, or 24 months).

maximum performance error of the panel occurred in yellow whole kernel corn run 13. Table VI-J illustrates decisively a relationship among storage temperature effects, which, although unexpected, occurs rather frequently, namely, the development of inferior flavor in samples stored at 25 F compared to that in samples stored at 35 F. Unsatisfactory temperature control at 25 F might account for these unexpected results. The occurrence of intermittent freezing and thawing could account for accelerated quality deterioration.

It is emphasized again that the system of panel performance evaluation used herein is very stringent and excludes from consideration some data that are included in a statistical evaluation. This system was used in order to present data representing the best panel performance separately, thus illustrating the degree of consistency or of inconsistency that appears in the pattern applying to the individual products concerned.

## BIOCHEMICAL CHANGES IN STORAGE

Brody, et al.,[2] conducted an investigation of biochemical changes, under three storage temperatures, in some of the canned foods packed in the project at Rutgers. Assays for reduced ascorbic acid, beta-carotene, riboflavin, and thiamine and analyses for total acidity and pH value in selected products, conducted by methods that have been described by the investigators,[2] are summarized in Tables VIII and IX. The magnitudes of changes during a 12-months period are expressed as percentages of values at the beginning of the storage period (initial concentration). Negative sign indicates reduction; no sign indicates increase.

Bongolan, et al.,[1] conducted thiamine assays on two baby foods over periods of six and nine months

**TABLE VII Percentages of Error by Panel in Results on Test Sample Identical to Reference Standard**

| Product | Run | Per cent Error | Product | Run | Per cent Error | Product | Run | Per cent Error |
|---|---|---|---|---|---|---|---|---|
| Oyster | 4 | 23 | Shrimp | 18 | 14 | Peas | 10 | 11 |
| Oyster | 17 | 7 | Milk | 7 | 17 | Peas | 21 | 20 |
| Pea Ham | 6 | 19 | Milk | 19 | 7 | Corn | 13 | 53 |
| Pea Ham | 15 | 10 | Gr. Beans | 12 | 15 | Corn | 23 | 30 |
| Veg. Beef | 5 | 13 | Gr. Beans | 22 | 20 | Tomato | 11 | 19 |
| Potato | 16 | 6 | Asparagus | 20 | 15 | | | |

**TABLE VIII* Biochemical Changes in HTST- and Conventionally-Processed Canned Foods during Storage at 3 Temperatures for 12 Months**

| Product | Process | Storage Temp (F) | Reduced Ascorbic Acid Initial Conc (mg/kg) | Reduced Ascorbic Acid Per cent Change | Beta-Carotene Initial Conc (meq/kg) | Beta-Carotene Per cent Change | Riboflavin Initial Conc (mg/kg) | Riboflavin Per cent Change | Thiamine Initial Conc (mg/kg) | Thiamine Per cent Change |
|---|---|---|---|---|---|---|---|---|---|---|
| Corn | HTST | 35 | 34 | — 6 | 970 | — 2 | | | 0.38 | —32 |
| | | 50 | | —26 | | —27 | | | | —29 |
| | | 80 | | —91 | | —34 | | | | —29 |
| | Conven. | 35 | 57 | —21 | 1130 | — 5 | | | 0.31 | 23 |
| | | 50 | | —21 | | — 5 | | | | 23 |
| | | 80 | | —32 | | —41 | | | | —29 |
| Green Beans | HTST | 35 | | | | | 0.32 | —16 | 0.36 | 0 |
| | | 50 | | | | | | —44 | | —11 |
| | | 80 | | | | | | —56 | | —31 |
| | Conven. | 35 | | | | | 0.24 | —33 | 0.19 | 10 |
| | | 50 | | | | | | —50 | | 0 |
| | | 80 | | | | | | —58 | | —21 |
| Green Pea Ham Soup | HTST | 35 | 19 | 21 | | | | | | |
| | | 50 | | 26 | | | | | | |
| | | 80 | | 16 | | | | | | |
| | Conven. | 35 | 19 | — 5 | | | | | | |
| | | 50 | | —11 | | | | | | |
| | | 80 | | —42 | | | | | | |
| Tomato Juice | HTST | 35 | | | | | | | 0.48 | 8 |
| | | 50 | | | | | | | | — 8 |
| | | 80 | | | | | | | | — 2 |
| | Conven. | 35 | | | | | | | 0.46 | — 6 |
| | | 50 | | | | | | | | —20 |
| | | 80 | | | | | | | | —20 |
| Oyster Stew | HTST | 35 | | | | | | | 0.78 | 5 |
| | | 50 | | | | | | | | 10 |
| | | 80 | | | | | | | | — 9 |
| | Conven. | 35 | | | | | | | 0.59 | — 3 |
| | | 50 | | | | | | | | 0 |
| | | 80 | | | | | | | | —25 |
| Potato Soup | HTST | 35 | | | | | | | 0.87 | —39 |
| | | 50 | | | | | | | | —32 |
| | | 80 | | | | | | | | —49 |
| | Conven. | 35 | | | | | | | 0.72 | 3 |
| | | 50 | | | | | | | | —11 |
| | | 80 | | | | | | | | —26 |

* Brody, et al[2]

**TABLE IX* Changes in Total Acidity and pH Value in HTST- and Conventionally-Processed Canned Foods During Storage at 3 Temperatures for 12 Months**

| Product | Process | Storage Temp (F) | Total Acidity Initial Conc (meq/g) | Total Acidity Per cent Change | pH Value Initial Value | pH Value Per cent Change |
|---|---|---|---|---|---|---|
| Green Beans | HTST | 35 | | | 5.9 | —2 |
| | | 50 | | | | —4 |
| | | 80 | | | | —7 |
| | Conven. | 35 | | | 5.6 | 0 |
| | | 50 | | | | —2 |
| | | 80 | | | | —7 |
| Green Pea w. Ham Soup | HTST | 35 | 2.1 | 10 | | |
| | | 50 | | 71 | | |
| | | 80 | | 119 | | |
| | Conven. | 35 | 2.5 | — 4 | | |
| | | 50 | | —16 | | |
| | | 80 | | —12 | | |
| Oyster Stew | HTST | 35 | 1.5 | 27 | | |
| | | 50 | | 40 | | |
| | | 80 | | 47 | | |
| | Conven. | 35 | 2.5 | — 4 | | |
| | | 50 | | 8 | | |
| | | 80 | | 16 | | |
| Shrimp Soup | HTST | 35 | 0.6 | —17 | | |
| | | 50 | | 0 | | |
| | | 80 | | 67 | | |
| | Conven. | 35 | 0.9 | —11 | | |
| | | 50 | | —11 | | |
| | | 80 | | 0 | | |

* Brody, et al[2]

**TABLE X* Thiamine Loss in Frozen and in HTST- and Conventionally-Processed Baby Foods**

| Product | Process | Storage Temp F | Length Storage (mos) | Initial Conc. (mg/kg) | Per cent Change |
|---|---|---|---|---|---|
| Plum w. Tapioca | Frozen | 0 | 9 | 0.12 | —71 |
| | HTST | 25 | 9 | 0.077 | —91 |
| | | 35 | | | —95 |
| | | 50 | | | —96 |
| | | 85 | | | —100 |
| | Conven. | 25 | 9 | 0.031 | —94 |
| | | 35 | | | —88 |
| | | 50 | | | —97 |
| | | 85 | | | —100 |
| Pea w. Ham Soup | Frozen | 0 | 6 | 0.844 | —58 |
| | HTST | 25 | 6 | 0.758 | —58 |
| | | 35 | | | —57 |
| | | 50 | | | —59 |
| | | 85 | | | —14 |
| | Conven. | 25 | 6 | 0.544 | —59 |
| | | 35 | | | —65 |
| | | 50 | | | —69 |
| | | 85 | | | —75 |
| Pea w. Ham Soup Enriched | Frozen | 0 | 6 | 4.315 | —35 |
| | HTST | 25 | 6 | 4.177 | — 3 |
| | | 35 | | | —13 |
| | | 50 | | | — 7 |
| | | 85 | | | —29 |
| | Conven. | 25 | 6 | 3.077 | —43 |
| | | 35 | | | —46 |
| | | 50 | | | —49 |
| | | 85 | | | —51 |

* Bongolan, et al[1]

respectively, the results of which, with the magnitudes of changes in thiamine content being expressed as percentages of the values at the beginning of the storage period, are shown in Table X.

Another aspect of biochemical analysis was the development of an assay procedure for vitamin $B_6$ and the application of the assay to a product, namely, cream of shrimp soup, after storage for two years, and the results are shown in Table XI.* The initial value of the vitamin was not determined.

**TABLE XI* Vitamin $B_6$ in Cream of Shrimp Soup after Storage for Two years**

| Process | Storage Temperature, F (Piridoxine Content, mg/kg) 25 | 35 | 50 | 85 |
|---|---|---|---|---|
| HTST | 0.53 | 0.72 | 0.60 | 0.90 |
| Conventional | 1.796 | 0.333 | 0.293 | 0.274 |

* Tryfiates and Babcock[6].

## Biochemical Changes

There are glaring inconsistencies in the data presented in Tables VIII and IX and some inconsistencies of minor nature in the data of Table X. Nevertheless, certain relationships seem to be shown with sufficient consistency to warrant conclusions in respect to them. These apply largely to thiamine, which is shown significantly to be better preserved by HTST- than by conventional-processing and by low storage temperature than by higher storage temperature. The data on riboflavin follow the same pattern as that on thiamine but riboflavin was studied in only one product and more data would be required to establish a typical pattern. Total acidity and pH value also follow a consistent pattern which is in harmony with expectations on theoretical grounds.

Reduced ascorbic acid and beta-carotene are affected by storage temperature similarly to thiamine but the indications as to the effects of heat in processing are reversed from those on thiamine, in other words, the former two vitamins were better preserved in the conventional process than in the HTST process.

* The work on vitamin $B_6$ was performed by G. P. Tryfiates and M. J. Babcock of the Agri. Biochemistry Department, Rutgers.[6]

These vitamins also need more study, as does vitamin $B_6$, for which the pattern of loss during storage shown in Table XI for HTST-processed product is the reverse of that shown for conventionally processed products. Also, the amount of vitamin $B_6$ which is shown by Table XI to have survived the 25 F storage following the conventional process is unrealistically large, indicating an erroneous value.

## TEXTURE

The texture component, which is manifested as resistance to shear, was studied in wax beans, Alaska peas, and whole kernel corn which had been stored for 12 months. No attempt was made to determine whether or not, for any one of the three products, a high shear resistance would be a desirable texture characteristic.

Retention of highest shear resistance in peas and wax beans was obtained in the frozen product, stored at 0 F. In the heat-processed products, highest shear resistance was found in those stored at 25 F. This was considerably lower, however, than that of the frozen product. Whole kernel corn, on the other hand, had slightly higher shear resistance after storage at 50 and 85 F than after storage at 25 or 35 F. This was

(*Continued on page* 144)

only slightly lower than that of frozen corn stored at 0 F. As stated, the degree of shear resistance that is most desirable to accompany other highest quality characteristics in the different products has not been determined.

## SUMMARY

For a bird's-eye view of the findings in this project in respect to the role of temperature in retaining quality in canned foods, let us say first that in flavor, color, texture and vitamin content, high temperature processed products consisting of five vegetables, five soups, evaporated milk, and two baby foods studied are substantially more nearly like those of the unprocessed products than are those in the same products after having been processed at lower temperatures, as in conventional-processing.

Secondly, considering seven products in the testing of which the flavor evaluation panel functioned the most proficiently, we find that all of them showed significantly better flavor after storage of from 6 to 24 months under refrigeration than when stored at 85 F and that one of these foods, viz., peas, showed similar superior retention of color, vitamins, and texture in refrigeration storage, three others, namely, oyster stew soup, pea with ham soup, and potato soup, showed like retention of superior quality in at least one of the other facets besides flavor when stored under refrigeration, and two others, viz., vegetable beef and shrimp soups, showed somewhat less conclusively than those named above a retention of superior quality in at least one of the other facets besides flavor when stored under refrigeration.

Several of the other 13 products tested, on which the flavor evaluation panel failed to operate satisfactorily, showed very definite retention of superior quality in one or more of the three facets, viz., color, texture, and vitamin retention, when stored under refrigeration.

These data seem to indicate that products should be considered individually in reaching a decision as to the question of whether or not the advantages that would accrue from storage of canned foods under refrigeration are sufficient to justify the cost of such storage. Additional comprehensive data are needed before intelligent decisions can be reached in regard to some products.

An important indication of the results of this study is that earlier observations which led to the belief that HTST-processed products lose their quality in storage more rapidly than conventionally-processed products, may have been misleading. It does not now appear so likely that this is true.

## CONCLUSIONS

Storage at temperatures within the range of from 25 to 50 F are shown to preserve quality in the lines of flavor, color, texture, and vitamin content in a variety of canned foodstuffs to a significantly greater extent than does storage at a high ambient temperature (85 F). Processing by high-temperature-short-time procedure has been shown to do likewise in comparison to heat processing by conventional method.

The question as to whether or not the magnitude of benefits shown in favor of low storage temperature for canned foods or of frozen or HTST-processed foods over conventionally-processed foods are sufficient to justify the use of these measures can be answered only after consumer reaction in respect to these benefits has been determined. It is felt by the authors that the data show some of these benefits to be of major proportions. It is also felt that experience has shown that quality improvements of comparatively small proportions in foodstuffs can, if they are dependably uniform, be responsible for a vast increase in consumer acceptance of a food. It is recommended, therefore, that further investigation be carried out directed toward the perfecting of advanced processing techniques and toward market testing of canned foods of improved quality which are held in refrigerated storage.

## ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of L. L. Gustafson and Z. Leranth for their assistance in the conducting of the tests of this project and that of L. L. Gustafson, H. Hallerman, and E. Kenkars for assisting in analyzing data for this report. The project is sponsored by The Refrigeration Research Foundation, the National Institutes of Health, the U. S. Department of Agriculture, the Smitherm Division of Hupp Corp., The Whirlpool Corporation, the American Can Company, and the Continental Can Company.

## REFERENCES

1. Bongolan, Dolores C., Joffe, Frederick M., Stier, Elizabeth F., and Ball, C. Olin. Low temperature handling of sterilized foods. Effect of processing, storage time and temperature on thiamine content of plum-tapioca and split-peas with ham. Paper to be presented at 22nd Annual Meeting, Institute of Food Technologists, Miami Beach, Florida, June 10-14, 1962.
2. Brody, Aaron L., Bedrosian, Karakian, and Ball, C. Olin. Low-temperature handling of sterilized foods. V. Biochemical changes in storage. Food Technol. 14, 552-556, 1960.
3. Epstein, Arnold I., and Ball, C. Olin. Low-temperature handling of sterilized foods. I. Design of equipment and outline of processes used. Food Technol. 14, 363-365, 1960.
4. Joffe, Frederick M., Stier, Elizabeth F., Bongolan, Dolores C., Epstein, Arnold I., and Ball, C. Olin. Low-temperature handling of sterilized foods. IV. Color and flavor of canned vegetables. Food Technol. 15, 507-510, 1961.
5. Joffe, Frederick M., Stier, Elizabeth F., Gustafson, Lanny L., Epstein, Arnold I., Hayakawa, Kan-ichi, and Ball, C. Olin. Low-temperature handling of sterilized foods. VI. Color and flavor of canned soups, tomato juice, and evaporated milk. Food Technol. 15, 510-514, 1961.
6. Tryfiates, George, and Babcock, M. J. Unpublished data. Department of Agricultural Biochemistry, Rutgers, The State University.

This article is a paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers The State University, New Brunswick, New Jersey.