better quality material was processed in larger lots, and hence subjected to conditions that would be apt to cause greater contamination from processing equipment. However, bacterial counts did reflect the sanitary conditions under which the products were prepared.

It is known that bacterial counts are not accurate. Also, the bacterial count of most food products has little significance as far as edible quality is concerned, until sufficient bacterial action has taken place to produce off-flavors. It is believed, however, that the bacterial count may be used in many cases to check and improve the sanitary and edible quality of foods. It should be pointed out that the dairy industry has used both viable plate and the microscopic count over a period of more than 50 years to check the sanitary quality of their products. Moreover, as the years have passed, this division of the food industries has from time to time made the bacterial standards stricter and more difficult to meet. In this instance, therefore, bacterial counts have been used to improve sanitary conditions in food processing plants.

Canadian authorities have set up bacterial standards in fish processing plants. This group has shown that bacterial contamination of fish fillets can be markedly reduced provided adequate sanitary precautions are observed.

Some authors have stated that the following conclusions can be drawn if the bacterial count of a frozen vegetable is below 100,000 per gram:

1. The product was blanched at high temperatures.
2. The product had been quickly and adequately cooled.
3. The packing plant was sanitary.
4. The packaging material was clean.
5. The method of freezing was rapid.
6. The vegetable had not been thawed after freezing.

If such information may be obtained from the bacterial count, it can be used as a worthwhile method of quality control. This type of information can be obtained from such a test if the available data are properly interpreted.

One fact which should be considered in interpreting the results of plate counts on frozen foods is that, during a storage period of six months in the frozen condition, the number of viable organisms may be decreased by as much as 50 to 75 percent.

It is believed that both plate count standards and microscope count standards can and should be established for frozen foods. However, when counts are made, a sufficiently large number of samples should be examined in each case.

It is proposed that the following suggested maximum bacterial counts shown in Table 1 might serve as a guide for the plant operator in judging the quality of his product.

Regarding the maximum counts proposed in Table 1, it is believed that a suitable tolerance has been included in each case. Frozen vegetables should contain essentially only those viable organisms which have been picked up from the processing line, since they should not be held long enough after blanching and prior to freezing to allow bacteria to reach the stage of active multiplication. If higher counts than those suggested as standards are found, it is indicated that active bacterial growth is taking place in materials collecting at certain points of the processing line. This means that better and/or more frequent cleaning operations and sanitizing procedures should be applied.

Higher counts have been suggested in the case of products such as spinach, broccoli, corn, and cauliflower which are of necessity handled in such a manner that they tend to pick up greater numbers of bacteria. The fact that many counts which have been made on these products over the years have been lower than those proposed in Table 1 would indicate that suitable plant sanitation can provide a product having bacterial counts within the proposed limits.

Table 1 .... Suggested Maximum Bacterial Counts for Certain Frozen Food Products

Product	Maximum Viable Count[a]	Maximum Total Microscopic Counts[a]
Peas	100,000	500,000
Lima Beans	100,000	500,000
Cut Corn	500,000	1,000,000
Spinach	150,000	500,000
Broccoli	500,000	1,000,000
Cauliflower	200,000	500,000
Green Beans	100,000	500,000
Breaded Shrimp	500,000	2,000,000
Fish Fillets	100,000	500,000
Eviscerated Poultry	5,000[b]	
Precooked Frozen Foods including poultry products	100,000	5,000,000
Egg products (whole egg, yolk, egg white)	200,000	
Cut Uncooked Meats	10,000[b]	
Hamburger	5,000,000	

[a] Counts are indicated on a per gram basis excepting in the case of eviscerated chicken and cut, uncooked meats.
[b] Counts indicated on a per square centimeter basis.

It has been found over a period of several years that the bacterial plate counts of uncooked breaded frozen shrimp are higher than might be expected for a product of this kind. It would appear, however, that the average plant is able to meet standards of 500,000 per gram. In any case, an attempt should be made to improve sanitation in packing plants preparing frozen, breaded shrimp products and, also, there should be an improvement in the condition of raw product as it is brought to port in so far as bacterial contamination is concerned. It is probable that a lowering of the bacterial count of frozen breaded shrimp would result in an improvement of the edible quality of the product. However, the presence of a certain number of bacteria of the coliform group is not considered adequate evidence of pollution. The total count may be more indicative of quality than tests for coliform bacteria.

Coliform counts should also be made on frozen breaded shrimp since tests have shown that most products of this kind contain some coliform bacteria. It is believed that the coliform count of breaded shrimp should not be higher than 50 per gram. The industry, moreover, should strive to prepare products containing no organisms of this kind. The fact that approximately 10 percent of the samples examined over a period of four years contained no coliform bacteria would indicate that the achievement of such a goal is entirely possible.

The limits proposed for fish fillets would not be exceeded in fish processing plants where sanitary procedures are practiced and should be lower than the values cited. Canadian workers have shown that it is possible to attain a product suitably low in count if fish are adequately washed prior to cutting, if care is taken not to contaminate the fillet with bacteria from the cutting board during skinning and if fillets are not allowed to stand around at such points as candling tables.

The counts proposed for eviscerated poultry can be attained without difficulty if the product is thoroughly washed and properly handled after evisceration. The number of viable bacteria on poultry surfaces could be reduced to a considerable degree by using in-plant chlorination procedures.

In work done in commercial laboratories (unpublished data) quality control procedures were set up so that both viable plate and microscopic counts were made on a number of precooked frozen food products. There were few cases in which viable plate counts higher than 1000 per gram were encountered. With precooked frozen meat products it was sometimes difficult to meet the standard of 5,000,000 per gram which has been proposed for microscopic counts. The high figure of 100,000 per gram for viable plate counts for precooked, frozen foods has been proposed because of certain precooked poultry products which have been found not to meet such a standard in certain cases. It appears that during the removal of poultry meat from the bone, after cooking, there is a considerable build up of bacteria. When these boned meat products are incorporated into a la king or pot pies, the meat is not heated to a high enough temperature to destroy all of the bacteria present. The industry should strive to improve the conditions of handling cooked poultry during and subsequent to the boning operation.

Since the eggs used for egg products contain relatively few bacteria when they are broken out, there is no reason why there should be a build up of more than 200,000 viable bacteria per gram before the product is frozen. The proposed limit has been based on average counts which have been found to be present in commercial egg products. Again there is some indication that an attempt should be made to improve the sanitary conditions of plants freezing egg products.

The highest viable plate counts have been suggested as a standard for hamburger. This commercial product is of necessity often prepared from meat that has a rather high bacterial count. In the past, an attempt has been made to meet a commercial standard of 1,000,000 per gram without success. A more liberal standard would, therefore, be indicated. Once ground, hamburger is subject to a rather rapid increase in the number of viable bacteria present. These factors necessitate a high bacterial tolerance under present conditions of processing.

It is evident that regulating agencies in this country will eventually set up bacterial count standards for, at least, some frozen food products. While much more information is necessary before such standards can be applied with good results, packers should have their own standards and strive to decrease the bacterial content of the foods which they produce and maintain them at a low level.

DEVELOPMENT OF BACTERIAL STANDARDS

It is considered that in the long run bacterial standards for frozen foods would be desirable for a number of reasons. If and when suitable standards can be worked out, they should serve as indexes of both sanitary and edible quality of such products. Such standards could be used to cause the careless producer to improve his product and the conditions of processing; this in itself would eventually benefit both producers and consumers. Bacterial standards for frozen foods would tend to improve the quality requirements of raw material used by processors. Finally, bacterial standards for frozen foods might serve as an incentive to produce better products as has been the case in the dairy industry.

It is evident that, if bacterial standards for frozen foods are to be enforced with good results, much more information is required than is now available concerning the total count that is indicative of poor sanitation or poor edible quality.

The sanitary significance of the presence of bacteria of the coliform group or of coagulase-positive *Staphylococci* in frozen foods is presently not known. Nor is it yet known what the presence of moderate numbers of these organisms signify from the standpoint of public health. To state that none of such organisms should be present in frozen foods would appear to be meaningless, especially if such a statement is not specified on the basis of a certain weight or volume of food.

The presently available tests to determine the number or the presence of coagulase-positive *Staphylococci*, *Salmonella* bacteria and bacteria of the *Shigella* group are anything but accurate or precise. Such tests must be modified and improved before they can be used with good results.

When bacterial standards for frozen foods can be set up in such a manner that failure to comply indicates insanitary foods, foods packed under insanitary conditions, or foods of poor edible quality, they will become meaningful in a legal sense. In order that enforcement agencies may be able to apply bacterial standards to frozen foods the requisite information must be available.

PUBLIC HEALTH ASPECTS

Regarding frozen foods, the diseases which would cause greatest concern are botulism, salmonellosis and staphylococcal gastroenteritis. Other bacterial diseases such as streptococcal gastroenteritis are known to have been caused by the ingestion of foods, but these are less frequently encountered than the diseases first listed. The question to consider is whether or not frozen foods are more apt to become vectors in the transmission of disease than are foods processed by other methods. It must be realized that any food, if grossly mishandled, may become the cause of an epidemic of food infection or food intoxication. Therefore, in considering frozen foods in relation to public health, it is necessary to predict what is likely to take place during handling of these products according to standard commercial practices.

The spores of *Clostridium botulinum* have survived in food materials at a temperature of approximately 3 F for at least 14 months and this food became toxic in 3 to 4 days after being thawed and held at high temperatures. When stored at temperatures below 50 F there was no production of toxin for at least 30 days although this might not have been the case had the inoculated organism been Type E.

Frozen spinach which had been previously inoculated with detoxified spores of *Clostridium botulinum* did not contain toxin 31 days after thawing and holding at 50 F. Toxin was produced in 3 to 4 days at 68 F.

Foods containing organisms of the *Salmonella* group must be held at 41 F or below after defrosting to prevent growth. *Salmonella* bacteria will survive freezing and storage at temperatures below freezing for a considerable length of time and enterotoxic *Staphylococci* have the same characteristics.

As far as frozen foods are concerned, it cannot be expected that either *Clostridia*, *Salmonella* or *Staphylococci* will all be destroyed by freezing and storage if present in the product when packed.

Regarding the growth of *Clostridium botulinum*, it has been found when certain frozen foods are defrosted and stored at temperatures which permit bacterial development, there is a tendency for growth of acid-forming organisms which prohibit the growth of putrefactive anaerobes. The danger of toxin production due to the development of *Clostridium botulinum* may be lessened by growth of acid-forming organisms which lower the pH below the range which allows the growth of this organism, however, the growth of acid-forming bacteria cannot always be relied upon to prevent growth of *Clostridia* in frozen foods after defrosting. It would appear that the question of whether or not frozen foods are dangerous from the standpoint of botulism becomes one of the probability that such foods may be held at temperatures above 40 F for some period of time. Past experience with commercial frozen foods in the United States would indicate that such a probability is not very great.