



Fig. 1 Data on Eggs Stored 37 Weeks at 30 F

enough. There is usually some coincident loss in flavor too, although this change develops more slowly.

The precise nature of the chemical changes accompanying these quality losses is not known. It is believed that they are not caused by any of the known enzymes. Recent work suggests that traces of certain sulfur compounds may be partially responsible. Beside temperature, carbon dioxide has a significant retarding effect on this type of quality loss.

Eggs which become badly contaminated with microorganisms spoil rather quickly. Some of the more common end results are black, red or green rots, eggs with crusted yolks, moldy eggs, etc. It is noteworthy however that occasionally eggs will become heavily contaminated without showing any outward manifestations of spoilage. Clean, fresh eggs seldom are contaminated internally. However, if they become wet, particularly under conditions of fluctuating temperatures, bacteria or molds or both may invade them and cause spoilage.

Egg odor and flavor is affected by many factors, including the feed and breeding of the hen, microbiological infection, chemical changes during storage, and absorption of odors from the environment. The last is particularly important in refrigerated warehousing. Strong odors like those obtained from certain fruits and vegetables (citrus fruits, apples, onions, potatoes, cabbages, etc.) are particularly to be avoided.

CONTROL OF QUALITY IN STORAGE

Maintaining Appearance

Temperature and carbon dioxide play very important roles in preventing changes in the appearance of eggs during storage. There is every advantage in lowering the temperature to the lowest possible degree without freezing (29 to 30 F), if eggs are to be kept in good condition for very long. Fig. 1 shows the effect of carbon dioxide content of the storage air on the appearance and flavor (due to chemical changes) of stored eggs. The rectangular area shows the range of optimum CO₂ concentration under commercial cold storage conditions. This same effect can also be obtained by sealing into the eggs the proper amount of carbon dioxide by oil dipping within 12 to 24 hr after laying. Recently, stabilizing of the thick white and killing the embryo has been accomplished by heat-treating the shell eggs. It has not been clearly demonstrated whether or not this *thermo-stabilizing* prevents yolk flattening and off-flavor development. Neither of these developments has been adopted to any great extent in the United States. Reliance is being placed almost entirely on temperatures within the range of 29 to 31 F for maintenance of quality during storage.

Bacteriological Spoilage

The storage of dirty or improperly cleaned eggs is the most common source of bacteriological spoilage. A large percentage of the contents of dirty eggs is contaminated with bacteria.

Improper washing increases the contamination but removes the evidence of dirt. Invariably most improperly cleaned eggs spoil during long storage. Insufficient research has been done to describe a perfect method for washing eggs for storage and it is probably not yet safe to recommend any procedure. Dry cleaning is a much safer means of cleaning eggs for storage. Eggs known to be cleaned should probably not be stored but should be marketed promptly or else frozen or dried.

Sweating of eggs removed from storage rooms gives rise to a serious contamination of the egg contents. If such eggs are held for an extended period thereafter, considerable spoilage may result.

Mold Spoilage

Mold growth on eggs can be controlled easily for long periods of time by keeping them in air below 85 percent relative humidity. However, such eggs will lose an appreciable amount of water under these conditions (commonly termed shrinkage), and commercially this lowers their market value. On the other hand, most molds grow luxuriantly on eggs if the relative humidity at the shell surface is more than 96 percent (where shrinkage is minimized). A slight growth commonly called *whiskers* occurs at 90-94 percent. The latter is often used as an indication of the desirable humidity level, although if eggs are kept at these humidities for extended periods the mold will eventually penetrate the egg and cause spoilage.

The optimum humidity for egg storage as ordinarily determined in the aisle of the storage room depends on a number of factors: air circulation, dunnage, moisture content of cases, fillers and flats, fluctuation of temperature, etc. It has been found safe to use 85-86 percent when no artificial circulation of air is used, and 87-92 percent with positive circulation.

Fillers, flats, and cases are sometimes treated with chemicals to minimize mold growth. The chlorinated-orthophenyl phenates (sodium salt) have been recommended but are not in general use.

Eggs for storage are frequently dipped in a colorless, odorless mineral oil. This treatment is sometimes referred to as processing, or oil processing. It greatly reduces shrinkage, and for such eggs the use of humidities above 85 percent is not of much practical value. To be effective in maintaining eating quality, the eggs should be treated within 24 hr after laying.

Odor Absorption

The so-called storage flavor in eggs can be greatly minimized by choosing cases, fillers, and flats which are new and which are relatively free of odor when moist. Further work needs to be done, however, if these odors are to be entirely eliminated from eggs stored for long periods of time. Rooms for egg storage should be carefully cleaned and deodorized prior to use. Freshly prepared whitewash is commonly applied to the walls, ceiling and floor at the start of each egg season. In addition eggs should not be stored in rooms with other products, especially citrus fruits, onions and potatoes.

Controlling Shrinkage

The shrinkage of shell eggs during storage can be largely controlled by shell treatment or a high relative humidity in the storage room. The simplest method is that of oiling the eggs prior to storage. It has become a practice in commercial egg producing areas to shell treat practically all eggs going into storage. While a number of studies have been made there seem to be no outstanding oils or methods of application. Reasonable care should be taken to avoid temperatures so high as to adversely affect the egg white. Also only naturally clean dry eggs should be treated. When un-oiled eggs are stored the relative humidity must be high if shrinkage is to

Table 1 Summary of United States Standards for Quality of Individual Shell Eggs

Quality	Specifications of Each Quality Factor			
	U. S. Grade AA	U. S. Grade A	U. S. Grade B	U. S. Grade C
Shell	Clean, unbroken and practically normal.	Clean, unbroken and practically normal.	Slight stains, unbroken, may be slightly abnormal.	Moderate stains, unbroken, but may be abnormal.
Air Cell	Must not exceed $\frac{3}{4}$ in. in depth and be practically regular.	Must not exceed $\frac{1}{4}$ in. in depth and be practically regular.	Must not exceed $\frac{3}{4}$ in. in depth, may show unlimited movement, but not bubbly.	May be over $\frac{3}{4}$ in. in depth and may be bubbly or free.
Yolk	Outline well centered and only slightly defined, free from defects.	Fairly well centered; outline fairly well defined and practically free from defects.	May be off center; outline well defined; may be slightly enlarged and flattened; may show definite but not serious defects.	May be off center, enlarged and flattened; may show germ development but no blood; may show other serious defects; outline plainly visible.
White	Clear and firm.	Clear and reasonably firm.	Clear but may be slightly weak.	Clear; may be weak and watery; small blood clots may be present.

Condensed from United States Standards for Quality of Individual Shell Eggs (U. S. Department of Agriculture 1955).

be minimized. As indicated above the limiting factor in this regard is mold growth, 92-94 percent rh seemingly being the limit for rooms with positive circulation.

EGG PRODUCTS

The past thirty years have seen a tremendous growth of the egg products industry. While frozen and dried eggs have been commercially produced in this country since before 1900, only recently have they become a substantial part of the output of the egg industry. Current frozen egg production amounts to several hundred million pounds annually, while egg solids production is at the rate of tens of millions of pounds.

A variety of egg products are produced. Among the more important frozen items are plain yolks, sugar yolk, whites, whole egg (mixed yolk and white in their natural proportions) and sugared yolk-white blends.

The solids content of commercial yolk varies from 43 to 47 percent depending on use: bakers usually take yolk of 43 to 44 percent; noodle and salad dressing manufacturers yolk of 45 to 47 percent. Whole egg (26 to 27 percent solids) and yolk-white blends (30 to 35 percent sugared egg solids) are mainly used by bakers. Egg solids products include albumen, yolk, and whole egg.

QUALITY FACTORS

The following criteria are generally used in evaluating egg product quality:

1. Odor
2. Color (for yolk)
3. Bacteria count
4. Solids and fat content (for yolk and whole egg)
5. Yolk content (for whites)
6. Performance

All users generally want a product which has a normal odor, is low in bacteria count (usually less than 1,000,000 per gm), and one which will perform satisfactorily in the items in which it is used. For noodles the user generally wants as high a solids content and color as it is possible to obtain. The baker is very particular about performance; the whites are especially prone to give trouble in angel food cakes due to excessive yolk content or previous heat treatment (such as in pasteurization). Other products where performance can be a problem are candy (using whites) and salad dressing (using yolks). Table 1 indicates government standards for egg quality.

PROCESSING, FREEZING, AND DEHYDRATION

Most of the production of egg products in the United States takes place in the Middle West and principally during the spring months. The raw material is commonly farm-run eggs, although a large volume of eggs with defective shells or other superficial defects are also used. The breaking and separating operations are usually done by hand, although at least two commercial mechanical breaking machines are available.

After breaking, the contents are separated or not depending on whether whole egg or yolk and whites are being produced. The products are then made homogeneous by simple mixing or, in the case of whites, usually by a special milling process. After filtration and standardization (including the addition of sugar or salt, if indicated) the products are either placed in 10 or 30 lb cans and transported to the freezer or to the drying plant. Whole egg or yolk products may be pasteurized at this stage although the practice is not yet very common. Whites are so easily damaged by heat treatment that they are rarely pasteurized.

Freezing is usually accomplished by air blast at temperatures down to -40 F directed at staggered piles of cans. Freezing time varies from 16 to 72 hr. Very rapid freezing may be accomplished by a number of obvious means, none of which has been shown to have any overriding advantages and none is in common use. If very rapid freezing is to be practiced, care must be taken to prevent the lid of the can from being forced off by the very rapid rise in the liquid core (due to expansion) against the lid.

Dehydration of eggs is accomplished by pan, foam, or spray drying. The whites, and occasionally the yolk and whole egg, are desugared prior to drying to improve storage life. The processing details are not important here. The final products range in moisture content from 2 to 16 percent, and are usually packaged in barrels or drums lined with moisture-vapor-proof liners. (Military specifications usually call for gas-packing in tin cans.)

STORAGE LIFE

Liquid egg products are extremely perishable and should be kept frozen at all times after production until used. Storage temperatures of 0 F or below will guarantee quality in frozen eggs for long periods of time. In fact products tested after ten years storage at 0 F have been found to be entirely satisfactory. Egg albumen (desugared egg white solids) is a highly