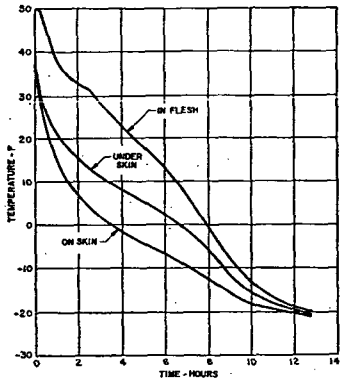
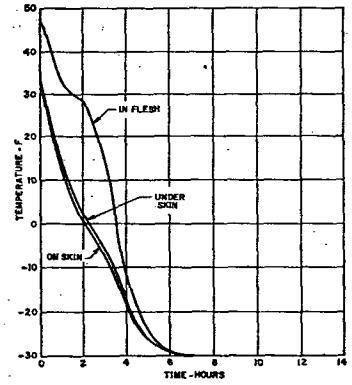


[a] For 21 lb, bronze tom turkeys on shelves in air blast.

Fig. 1 .... Temperature during Freezing of Packaged, Ready-to-cook Turkeys[a, 13]

could be matched by air blast freezing only at an air blast temperature of −100 F. Combinations of immersion freezing and air blast freezing were tested. A minimum immersion time at −20 F of 20 min for chickens and 40 min for turkeys was necessary to obtain a white appearance, typical of immersion freezing, in birds subsequently frozen on open shelves in a −20 F, 300–500 fpm air blast. The light colored chalk-



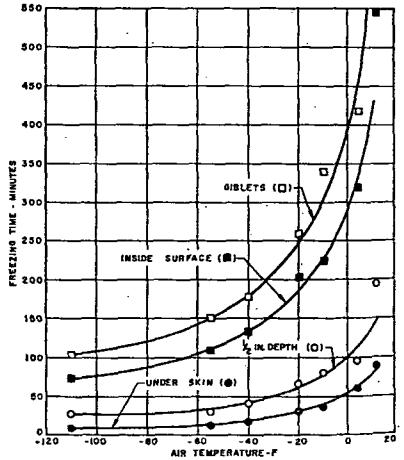
[a] For 7 lb, bronze tom turkeys on shelves in air blast.

Fig. 2 .... Temperature during Freezing of Packaged, Ready-to-cook Turkeys[a, 13]

like appearance of immersion frozen poultry was maintained indefinitely in −20 F storage, but darkened after 6 weeks at 0 F or 2 weeks at 20 F.

Comparison of various liquids (methanol, salt brines and glycols) that might be used in immersion freezing revealed that freezing times depended mainly on viscosity of the liquids and were maximum in glycerol and minimum in calcium chloride brine. Increased agitation decreased freezing times in the surface layers by as much as 50 percent. Spraying the the liquid was as effective in reducing freezing times as the highest rate of agitation used. Advantages claimed for immersion freezing are lighter, more pleasing appearance; high rate of heat transfer that makes a line operation feasible; lower initial and upkeep costs than air blast; and possible use in combination with subsequent air freezing. Possible disadvantages include lack of uniformity of frozen appearance, development of leakers due to pinpoint holes or cracks in packaging film, the question of consumer acceptance of the chalk-white birds and lack of versatility for freezing all types of material.

Typical freezing rate curves are given in Figs. 1 to 5, which illustrate the effect of bird size and depth below skin surface, temperature and velocity of the cooling medium, and type of medium (air versus liquid). Pflug has reviewed[18] the relative efficiencies and requirements for air and liquid immersion freezing, and points out the critical importance of the conductance of the coolant-product interfacial film, citing a film heat transfer coefficient of 3 Btu per (sq ft) (hr) (F deg) for air at −20 F and 500 fpm, compared to 30 Btu per (sq ft) (hr) (F



[a] Freezing time is the time required for temperature to fall from 32 to 25 F.
[b] For 5–8 lb chickens with initial temperature of 32–35 F and with air velocity of 450–550 fpm.

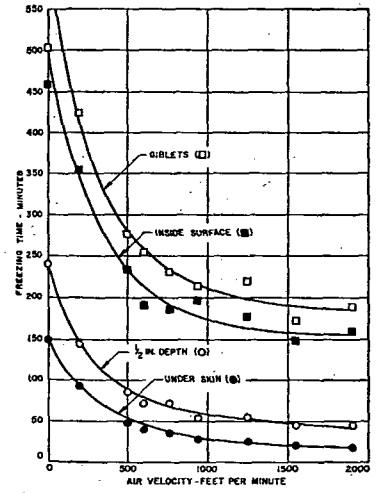
Fig. 3 .... Relation between Freezing Time and Air Temperature[a, b, 12]

deg) for sodium chloride brine at 0 F and a velocity of 5 fpm. For calculating refrigeration requirements for freezing ready-to-cook poultry, Pflug gives a freezing point of 27 F, specific heat above freezing of 0.70 Btu per (lb) (F deg), a latent heat of fusion of 106 Btu per lb, and a specific heat below freezing of 0.37 Btu per (lb) (F deg).

QUALITY PRESERVATION IN STORAGE AND MARKETING

Important qualities of frozen poultry include appearance, flavor and tenderness. If these are not optimum, then the convenience and flexibility of use of the frozen product will not in themselves be sufficient inducement to the housewife. Optimum quality requires care in every phase of the marketing sequence, from the frozen storage warehouse, through transportation facilities, wholesaler, retailer and finally to the frozen food case or refrigerator in the home.

Darkening of the bones is a condition peculiar to frozen poultry as distinguished from chilled poultry. Freezing and defrosting of young chickens are responsible for darkening of bones.[19] During the freezing and defrosting processes, some of the heme pigment normally contained in the interior of the bones of particularly young chickens leaches out through spongy areas, and discolors the adjacent tissues. This in no way affects the palatability of the product, because the pigment is a natural tissue pigment which, after being cooked is known as hematin and is responsible for the cooked appear-



[a] Freezing time is the time required for temperature to fall from 32 to 25 F.
[b] For 5–8 lb chickens with initial temperature of 32–35 F and with air temperature of −20 F.

Fig. 4 .... Relation between Freezing Time and Air Velocity[a, b, 12]

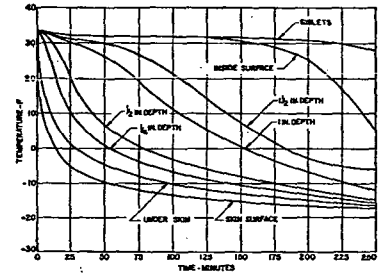


Fig. 5 .... Temperatures at Various Depths in Breast of 15 lb Turkeys During Immersion Freezing at −20 F[18]

ance of all meats. The rate of freezing has no marked influence in preventing this discoloration. Also, the period of time between slaughter and freezing has no significant effect on the color of poultry bones or on the displacement of pigment from the interior of the bones to adjacent tissues. Brant and Stewart found[20] that development of dark bones was greatly reduced by a combination of freezing and storage at −30 F and immediate cooking after rapid thawing. Aside from this combination, freezing rate, temperature of storage, length of storage, and temperature fluctuations during storage were not found to have an effect of practical importance. Further research suggested that freezing and thawing not only liberated hemoglobin from the bone marrow cells but also modified the bone structure to permit penetration by the released pigment. Roasting pieces of chicken 30 min prior to freezing reduced discoloration of the bone. Ellis and Woodroof found[21] that heating legs and thighs to 180 F before freezing effectively controlled meat darkening. Methods of preheating, in order of preference, included microwave oven, steam, radiant heat oven, and deep fat frying.

During storage, poultry may become dehydrated, yielding a condition known as *freezer burn*. Dehydration can be controlled by humidification, the lowering of storage temperatures or by packaging the product adequately. Aside from adversely affecting the appearance of the product, dehydration, unless it is severe, does not impair quality. If storage temperatures of 0 F or lower are maintained, freezer burn is usually the factor limiting the length of time that poultry can be held in storage without adequate packaging.

Koonz, Trelease, and Robinson reported[22] the results obtained when holding poultry wrapped in moisture-proof sheet cellophane in storage at −20, −10, 0, 10, 20 and 28 F. A record was made at various intervals over a period of a year concerning color, freezer burn, moisture loss, peroxide values and palatability scores of fat and meat. The results indicated that at storage temperatures of 0 F or lower, freezer burn was usually the factor which limited the time that poultry could be held in storage.

Wills et al found[23,24] that the appearance of poultry suffered greatly when stored at 20 F. The most serious defects were microbiological changes, desiccation and development of *old* odors. At 0 F, changes affecting quality were less serious. Serious changes in flavor and juiciness occurred in poultry which had been frozen three to nine months at 10 F and higher.