Farm Structures
FACTSHEET

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REFRIGERATION REQUIREMENTS FOR FRUITS & VEGETABLES

When fruits and vegetables are harvested, they are cut off from their source of water and nutrition and soon start to deteriorate. They lose weight, texture, flavour, nutritive value and appearance. In other words, they lose quality and potential storage life. Both time and temperature are important factors in post-harvest product deterioration. Cooling controls the rate of loss of quality by slowing the rate of living (respiration). The warmer the temperature, the faster the deterioration and the shorter the storage life; conversely, the cooler the temperature, the slower the deterioration and the longer the storage life. The more quickly the product is cooled, the longer it will remain marketable. There is a rule of thumb for perishable crops that, every hour lost before cooling to storage temperature results in a loss of one day or more of shelf life.

The greatest need to cool occurs immediately after harvest, coincident with the greatest load required for refrigeration equipment. The produce is usually warm when harvested; that warmth, or field heat, must be removed because the produce respires and produces heat at a very high rate. A cooler must be able to handle that peak demand or rapid deterioration will occur.

To achieve rapid cooling of the produce, various methods may be used, such as hydro cooling, contact icing, vacuum cooling and forced air cooling. Hydro cooling is simply the use of cold water spray or immersion for direct cooling of the produce and is most commonly used for sweet corn, asparagus and celery. Contact icing employs the spreading of crushed ice over the produce and is particularly advisable for products that lose moisture rapidly, such as lettuce, radishes and bunched carrots. Vacuum cooling is primarily used in areas where large volumes of lettuce, celery and other leafy crops are grown. This method is not normally used for small on-farm situations. Forced air-cooling involves forcing cold air into containers and through the produce. This technique is successfully used to pre-cool strawberries and raspberries for shipment to fresh market outlets, either private or commercial. High relative humidities are required for forced air-cooling or desiccation rates will be high.

Room cooling in a refrigerated room is another form of cooling where air passes around the containers but is not forced directly through the produce. Cooling rates are slower than other methods listed above; however, this cooling method is far better than no cooling at all. Furthermore, the room cooler can be used for holding crops prior to shipment or direct sales. The returns of the various treatments must be assessed prior to spending money to achieve these optimum cooling rates.

The quality of fresh produce in storage depends, to a great extent, on the humidity in the storage. Humidity is more difficult to control than temperature and often does not receive adequate consideration when designing cold storages. Most fruits and vegetables should be stored at relative humidities of between 85% to 95%. The best way to maintain high humidity in a cold storage is to use large evaporator coils. A recommended temperature differential between the desired storage room temperature and the actual coil or refrigerant exhaust temperature is 8°F or less. To achieve this low temperature differential means that large evaporator coils will be required and this will be more expensive.

Design of systems for cooling, freezing or storing foods requires values for thermal properties of various products. The accompanying tables provide specific properties for fruits and vegetables. The properties include the optimum storage temperatures for short term and long term storage of products. Although not a thermal property in itself, water content significantly influences all thermal properties; as a matter of fact, the values of specific heat and latent heat of fusion are calculated directly from the water content.

Values for relative humidities are provided to maintain optimum product quality without significant losses while in storage. The specific heat values given for products above and below freezing are required to calculate the product load in sizing a refrigeration machine. Similarly, when freezing products, the latent heat of fusion is required.

Products stored above the highest freezing point or, more specifically, at the storage temperature will respire. The values given in the accompanying table provide the designer with information on heat production during the first day or so of storage (high values), also, values for respiration are given when the product has reached storage equilibrium (lower values).

STORAGE REQUIREMENTS AND PROPERTIES OF FRUITS AND VEGETABLES

Product	Storage Temp. Long °F	Storage Temp. Short °F	Water Content %(mass)	Humidity %R.H.	Specific Heat Above Freezing BTU/lb/°F	Specific Heat Below Freezing BTU/lb/°F	Latent Heat of Fusion BTU/lb.	Highest Freezing Point °f	*Respiration at storage Temperature BTU/lb/day
Fruits									
Apples (fresh)	30-32	38-42	84	85-90	0.87	0.45	120.5	30.0	3.37-0.45
Apricots	31-32	40-48	85	85-90	0.88	0.46	121.9	30.0	0.56-0.63
Blackberries	31-32	42-45	85	85-95	0.88	0.46	121.9	30.6	1.71-2.53
Blueberries	30-32	35-40	82	85-95	0.86	0.45	117.6	29.1	0.26-1.15
Cherries (sweet)	31-32	40	80	80-90	0.84	0.44	114.7	28.8	0.45-0.60
Cranberries	36-40	40-45	87	85-95	0.90	0.46	124.8	30.4	0.45-0.52
Currants	31-32	40-45	85	85-95	0.88	0.46	121.9	30.2	n/a
Gooseberries	30-32	35-40	89	85-95	0.91	0.47	127.6	30.0	0.74-0.97
Grapes (vinifera)	30-32	35-40	82	80-90	0.86	0.45	117.6	28.2	0.15-0.26
Peaches (fresh)	31-32	50	89	85-90	0.91	0.47	130.5	30.4	0.41-0.71
Pears	29-31	40	83	85-90	0.86	0.45	119.0	29.1	0.30-0.74
Plums	31-32	40-45	86	80-90	0.89	0.46	123.3	30.6	0.22-0.33
Prunes	31-32	40-45	86	80-90	0.89	0.46	123.3	30.6	0.22-0.33
Raspberries	31-32	40-45	84	80-90	0.87	0.47	120.5	30.9	1.93-2.75
Strawberries	31-32	42-45	90	80-90	0.92	0.47	129.1	30.6	1.34-1.93

Vegetables									
Asparagus	32	40	93	85-95	0.94	0.48	133.4	30.9	3.01-8.82
Beans, snap	32-34	40-45	89	85-95	0.91	0.47	127.6	30.7	3.76-3.83
Beans, dried	36-40	50-60	11	70	0.29	0.23	n/a	n/a	n/a
Beets, roots	32-35	45-50	88	95-98	0.90	0.46	126.2	30.0	0.60-0.78
Broccoli	32-35	40-45	90	90-95	0.92	0.47	129.1	30.9	2.05-2.34
Brussels sprouts	32-35	40-45	85	90-95	0.88	0.46	121.9	30.6	1.71-2.64
Cabbage	32	45	92	90-95	0.94	0.48	132.0	30.4	0.45-1.49
Carrots (roots)	32	40-45	88	95-98	0.90	0.46	126.2	29.5	1.71
Cauliflower	32	40-45	92	85-95	0.94	0.48	132.0	30.6	1.97-2.64
Celery	31-32	45-50	94	90-95	0.95	0.48	134.8	31.1	0.78
Corn, sweet	31-32	45	74	85-95	0.79	0.42	106.1	30.9	4.65
Cucumbers	45-50	45-50	96	90-95	0.97	0.49	137.7	31.1	2.53-3.20
Eggplant	45-50	46-50	93	85-95	0.94	0.48	133.4	30.6	n/a
Garlic (dry)	32	50-60	61	65-70	0.69	0.38	87.5	30.6	0.33-1.19
Leeks	31-32	45-50	85	90-95	0.88	0.46	121.9	30.7	1.04-1.79
Lettuce (head)	32	45	95	95-98	0.96	0.49	136.3	31.6	1.00-1.86
Mushrooms	32-35	55-60	91	80-90	0.93	0.47	130.5	30.4	3.09-4.80
Onions (green)	32	50-60	89	90-95	0.91	0.47	127.6	30.4	1.15-2.46
Parsnips	32-34	34-40	79	95-98	0.83	0.44	113.3	30.4	n/a
Peas, green	32	40-45	95	85-95	0.79	0.42	106.1	30.9	3.35-5.13
Peppers (sweet)	45-50	40-45	95	90-95	0.94	0.48	132.0	30.7	1.60
Potatoes (white)	36-50	45-60	78	85-95	0.82	0.43	111.9	30.9	0.63-0.74
Pumpkins	50-55	55-60	91	70-75	0.93	0.47	130.5	30.6	n/a
Radishes	32-34	40-45	95	95-98	0.96	0.49	136.3	30.7	0.60-0.63
Rhubarb	32-34	40-45	95	90-95	0.96	0.49	136.3	30.4	0.89-1.45
Spinach	32	45-50	93	90-95	0.94	0.48	133.4	31.5	5.06
Squash (winter)	50-55	55-60	95	70-75	0.88	0.46	119.1	30.8	1.30-1.41
Tomatoes (ripe)	40-50	55-70	94	85-90	0.95	0.48	134.8	31.1	1.56
Turnip (roots)	32	40-45	92	90-95	0.94	0.47	132.0	30.0	0.97

*Use higher values for first day storage and lower values, when product is at an equilibrium state, for longer storage period.

Data largely taken from 1986 A.S.H.R.A.E. Refrigeration handbook.

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