ONION
Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

ONIONS: Post-Harvest Operation

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Last reviewed: 28/08/2003

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Preface

The post-production sector accounts for about 60% of the economic activities in most developing countries. The growing, handling, storage and marketing of onions is an important part of these economic activities. In many growing regions, it is a major source of income for rural families who sell their produce in local, regional and international markets. Onion are also grown in large quantity in developed countries and these products dominate the international market partly due to their higher quality and longer storage life which results from the application of improved post-harvest systems. The objective of this chapter is to examine the post-harvest handling and storage technology for onions, which assist in quality maintenance.

Fig. 1. Onion bulbs

1. Introduction

1.1 Economic and Social Impacts of Onions

Onions *(Allium cepa* L.) are important vegetable crops in most parts of the world, particularly the varieties that are grown for bulbs. In terms of global weight of vegetables produced, at nearly 28 million tonnes per annum, only tomatoes and cabbages exceed bulb onions in importance.

1.2 World Production and Trade

Onions are important crops in the tropics, which account for nearly 30% of total global production. Although some tropical countries are net importers, export potential of onions is developing in several tropical regions partly because if dried and packed properly, the bulbs can be transported for considerable distances without deteriorating. World-wide production of onions has increased during the past five years (Table 1), and global onion trade is estimated at about 3 million Mt annually, worth about US$700 million during this period.

Table 1: Global production and trade in dry onions

	2000	1999	1998	1997	1996	1995
Production (Mt)	46,962,196	46,032,893	40,750,495	39,587,473	38,696,103	37,514,029
Exports – Qty (Mt)	-	3,180,559	3,261,912	2,891,494	3,164,300	3,047,723
Exports – Value (1000US$)	-	738,489	918,543	727,672	716,953	955,326

Source: FAOSTAT, 2000

1.3 Primary product

Onions *(Allium cepa* L.) are grown mainly as food materials. They are highly valued for their flavour and for their nutritional value in supplying minor constituents such as minerals and trace elements (Table 2). The bulbs are boiled and used in soups and stews, fried or eaten raw. They are also preserved in the form of pickles. Onion leaves, especially the Spring onion, are also used in salads and soup. There is a dearth of information on secondary and derived onion products.

Table 2: Contents of major nutrients and vitamins in onion bulbs (*Allium cepa var. cepa*) and leaves (*Allium fistulosum*) per 100g edible portion.

Constituent	Quantity	
Major nutrients	Bulbs	Leaves
Water	87	90 91
Calories	48	36 30
Protein (g)	1.5	1.8 1.6
Fat (g)	trace	0.5 0.3
Carbohydrate (g)	11	6 6
Fibre (g)	0.5	1.0 0.8
Calcium (mg)	30	40 55
Phosphorous (mg)	-	- 41
Iron (mg)	0.5	3.0 1.1
Vitamins		
ß-carotene equiv. (µg)	trace	328 630
Thiamine (mg)	0.04	0.05 0.06
Riboflavin (mg)	0.02	0.10 0.08
Niacin (mg)	0.3	0.5 0.5
Ascorbic acid (mg)	10	50 19

Source: (Platt, 1962; FAO, 1972

1.4 Requirements for export and quality assurance

The requirements for international quality standards for food products is presented in Table 3, and this must be interpreted and applied for each type of produce. For onions, a comprehensive interpretation has been documented (Brice et al., 1997). This interpretation applies to onions grown from cultivars of *Allium cepa* L. to be supplied fresh to the consumer

with the exception of (a) onions with their leaves and stems still green (fresh onions), (b) onions intended for planting (basic material), and (c) onions intended for processing. Only the minimum requirements (these apply to both classes) are presented here (Table 4). The onions have to be packed in new and clean packing material, that they are saved appropriately and not subjected to external and internal changes. Both sorting and grading must be supervised by well-trained personnel in order to achieve and maintain good quality. The packages have to be designated concerning packer, kind and origin of product and trading marks.

Table 3: Summary of the Requirements for the International OECD Quality Standard

Requirements	Class I	Class II
Market value	Good Quality	Marketable Quality
Minimum requirements	Intact (flesh not exposed) Sound; produce affected by rotting or deterioration so as to make it unfit for consumption is excluded in all cases Clean; practically free from any foreign matter Sufficiently dry for the intended use (in the case of pickling onions, at least the first two dry skins and the stem should be completely dry) Free from abnormal external moisture Free from foreign smell and/or taste The stem must be twisted or clean-cut and must not be more than 4 cm long (except for twisted onions)	
Quality requirements		
Consistency	Firm and compact	Reasonably firm
Shape	Typical of the variety	Not typical of the variety
Colour	Typical of the variety	Not typical of the variety
Defects	Without evidence of growth	Early evidence of growth (not more than 10% for any given batch)
	Without hollow or tough stems Free from swelling caused by abnormal development Practically free from root tuffs	
Allowed		Small healed cracks Traces of rubbing Slight marking caused by parasite or disease Slight bruising, healed, unlikely to impair keeping quantities
	Light staining not affecting the last outer skin protecting the flesh	Staining not affecting the last dry outer skin protecting the flesh
Sizing	Compulsory Minimum diameter: 10 mm Maximum deviation in diameter in each pack: 5 mm when graded between 10 mm and 20 mm 10 mm when graded between 15 mm and 25 mm 15 mm when graded between 20 mm and 40 mm 20 mm when graded between 40 mm and 70 mm 30 mm when graded between 70 mm and plus	
Tolerance		
Quality	10%	10%
Size	10%	10%
Packaging		
Presentation	In layers In bulk In 'strings' (of not less than 16 bulbs with completely dry stems)	
Uniformity	Same origin, variety	
Packaging	Free from foreign bodies	

Source: (Brice et al., 1997).

Table 4: Interpretation of the OECD International Quality Standard for Minimum Requirements for Onions (*Allium* cepa L.)

a) Intact (outer skin included)
The onions must not have suffered any mutilation during growth or at any time of pulling, removal of the stem, packaging, handling, or any other operation.
When onions are stored and/or handled in a dry atmosphere, the outer dry skin may split and disappear. Thus small cracks in the outer dry skin, due to low air humidity, are allowed. As long as the flesh is not visible small cracks in the outer skin are not considered defects.
Also, absence of a part of the outer skin is allowed provided there are more dry skins and the flesh is not revealed.
b) Sound
The onions must not be rotten or seriously affected by disease or parasites.
c) Clean
The bulbs must be free from any impurity, which may materially alter the appearance or quality.
d) Free from any damage due to frost
Onions affected by frost rot rapidly after handling in a frozen condition and when the temperature rises above 0°C. Therefore they must not be allowed to travel.
The onion is regarded as frost-bitten when more than two of the outer layers of the flesh are affected and the flesh has a waxy appearance. A waxy appearance of the outer layers of the flesh can also be caused by mechanical handling. This slight defect does not affect the edibility of the onions. This waxy appearance of the outer layers disappears in a few days after ventilation.
e) Sufficiently dry for the intended use
At the beginning of the season, onions are frequently pulled before fully developed. Although they cannot be stored, they must be covered by a dry skin, which may be sufficiently dry for no moisture to be pressed out by the fingers, in order that any subsequent heating may be avoided. The onions must be pulled when ripe enough to meet current market standards, i.e. such that they remain sufficiently firm and do not become soft or spongy.
For onions pulled when fully developed, the expression 'sufficiently dry' means that in wet weather the bulbs may be slightly wet in view of the hygroscopic properties of their outer skin, but the leaves near the neck must be fairly dry.
f) Free from abnormal external moisture
At the time of shipment onions must show no signs of excessive moisture due to unnatural causes (such as prolonged exposure to rain) likely to impair their capacity for travel or keeping qualities. The condensation observed immediately after cold storage is not regarded as 'abnormal'.
g) Free of foreign smell or taste
This refers especially to produce that has been in poorly kept or unsuitable cold storage facilities and which may have absorbed the odour given off by other produce on the premises.
i) The stems must be twisted or clean-cut and must not be more that 4 cm long (except for stringed onions)
Onions are prepared either by hand or mechanically. Account will thus be taken of the overall appearance of the batch, and the presence of more than 20% of stems over 4 cm long in any one lot will be accepted as evidence that minimum requirements have not been met.
Source: (Brice et al., 1997)

1.5 Consumer Preferences

Certain varieties of onions are preferred for certain dishes. For instance, red onions are most commonly used in salads while the white and cream varieties are seldom used in salads. The

Spring onions are also used mainly in salads and soup. Consumer preference is dictated by the level of onion pungency and type of food. Cultivars that have poor storage quality are generally less pungent

2. Post-Production Operations

2.1 Pre-harvest Operations

The condition of onion leaves is a good indicator of the maturity and general state of the bulb. Bulb onions which are to be stored should be allowed to mature fully before harvest and this occurs when the leaves bend just above the top of the bulb and fall over. As a practical guide, farmers should conduct sample counts on the number of bulbs, which have fallen over in a field; and when the percentage of bulbs, which have fallen over, reaches about 70-80% then the entire crop should be harvested. Harvesting could commence earlier when 50-80% of the tops have gone over, before it is possible to see split skins exposing onion flesh Storage losses at optimum maturity are normally lower than those harvested before the tops collapse. Bulbs generally mature within 100-140 days from sowing, depending on the cultivar and the weather. Spring onions mature for harvesting after 35-45 days from sowing. Harvested crop should be allowed to dry or cure and ripen in the sun for several days after lifting. Onions can yield up to 5 t.ha-1 under good growing and management conditions.

2.2 Harvesting & Transport

Manual harvesting is the most common practice in most developing countries. This is normally carried out by levering the bulbs with a fork to loosen them and pulling the tops by hand. In developed countries, especially in large scale farms, mechanical harvesting is commonly used. The harvesting techniques adopted are influenced by weather condition at harvest time. In areas where warm, dry weather occurs reliably, the curing and bagging of the crop can be done in the field (two phase harvesting). In wetter, temperate regions, mechanical harvesting and artificial heating and ventilation for drying are essential for reliable production of high quality bulbs on a large scale.

The following steps are followed during two-phase harvesting of onions: (a) mowing the leaves (if necessary); (b) stubbing, undercutting and sieving the onions to remove stones and clods; (c) roll the soil in the row to get a plane surface; (d) drying the bulbs (windrowing) 8 to 10 days in the field; (e) turning the bulbs 1 to 2 times; (f) harvesting, sieving and hand-grading, overloading into a trailer or in crates; and (g) transport. For one phase harvesting usually commercial potato harvesters have been adapted. After mowing the leaves the crop is immediately harvested, sieved, hand graded and loaded onto the trailer. Because of the additional operations involved, labour costs for two-phase harvesting are about 30 to 100 % higher than for one phase harvesting. The main disadvantage of one-phase harvesting is the high energy consumption required for mechanical drying. Using combine harvesting, the standardised working hours has been calculated to be 2.7 to 2.9 $hr.ha^{-1}$ for stubbing, 2.4 to 2.6 $hr.ha^{-1}$ for turning and 8.9 to 11 $hr.ha^{-1}$ (KTBL, 1993).

Harvested bulbs are placed in containers (basket, bins) or tied into bunches and placed directly on the floor of a trailer for transport. These trailers can be pulled by an animals (such as donkey) or mechanical transport such as a tractor. Both packaging and transport systems must be selected to ensure minimum handling damage to produce. Hard surfaces should be cushioned with leaves, foam or other appropriate force decelerators.

2.3 Curing & Drying

Both curing and drying remove excess moisture from the outer layers of the bulb prior to storage. The dried skin provides a surface barrier to water loss and microbial infection,

thereby preserving the main edible tissue in a fresh state. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the crop to ripen before fresh consumption or long-term storage (Opara and Geyer, 1999). This process of dehydration is sometimes called 'curing', but the use of the word 'curing' for onion drying is rather inaccurate since no cell regeneration or wound healing occurs as in other root crops such as yam and cassava. Drying reduces bulb weight and since they are sold mostly on a weight basis, achieving the desired level of dehydration is critical. Weight losses of 3-5% are normal under ambient drying conditions and up to 10 % with artificial drying.

In traditional small-scale operations, onion drying is carried out in the field in a process commonly called 'windrowing'. It involves harvesting the mature bulbs and laying them on their sides (in windrows) on the surface of the soil to dry for 1 or 2 weeks. In hot tropical climates, the bulbs should be windrowed in such a way to reduce the exposed surface to minimise damage due to direct exposure to the sun. In wet weather, the bulbs can take longer time to dry and may develop higher levels of rots during storage. The side of the bulb in contact with wet soil or moisture may also develop brown strains or pixels, which reduce the appearance quality and value. Obviously, successful windrowing is weather dependent and therefore cannot be relied upon for large scale commercial onion production business. Bulbs harvested for storage require in total 14-20 days of ripening or drying before being stored. Harvested onions may also be placed in trays, which are then stacked at the side of the field to dry. In some tropical regions, the bulbs are tied together in groups by plaiting the tops, which are then hung over poles in sheds to dry naturally.

Harvested bulbs can also be taken straight from the field and dried artificially either in a store, shed, barns, or in a purpose-built drier. This method is commonly used when crops are stored in bulk but it can also be applied to bags, boxed or bins. Under this method, bulbs are laid on racks and heated air is rapidly passed across the surface of the bulbs night and day [O'Connor, 1979; Brice et al., 1997]. Drying may take 7-10 days and is considered complete when the necks of the bulbs have dried out and are tight and the skins shriek when held in the hand. The control of humidity level in the store is critical. Under very high humidity, drying is delayed and fungal infection can increase. However, if relative humidity is too low (below 60%), excessive water loss and splitting of the bulb outer skins can occur, resulting in storage losses and reduction of bulb value. Placing onions on wire mesh in well ventilated conditions and using air at about 30°C, 60-75% rh and 150 $m^3.h^{-1}.m^{-3}$ is generally recommended for mechanical drying of onions.

2.4 Cleaning

Freedom from any impurity, which may materially alter the appearance or eating quality, is essential. Soil and other foreign materials must be removed and badly affected produce must be discarded. Cleaning may be carried out using air or by manually removing unwanted materials on the bulb surface. Care should be taken to avoid physical injury on the bulb during these operations.

2.5 Packaging

General Information

Good packaging for onions must meet the following criteria: (a) strong enough to retain the required weight of onions under the conditions of transport and storage, (b) allow sufficient ventilation for the air around the bulbs to maintain relative humidity in the required range, and (c) in many circumstances, provide a means of displaying legally required and commercially necessary information (Brice et al., 1999).

There are many traditional methods of holding onions for transportation and/or storage that do not fit into conventional packaging classifications. These include 'string of onions', shelves and loose bulk In 'string of onions' packing, the bulbs are tied together by means of their tops to produce a bunch of bulbs is also a form of packaging. This is suitable for transporting small quantity of crop, and during storage, the bunches are hung from the roof or from special racks. Shelves for onion handling and storage are made from either wooden slats or metal mesh on a wooden or metal frame, and are usually fixed in position with the bulbs loaded and unloaded in the store. Ventilation (natural or forced) is usually achieved by passing air over the shelves. To achieve adequate aeration of the bulbs, the depth of bulbs on the shelves should be limited to 10 cm.

Onions are also stored loose bulk (instead of containers) by heaping the bulbs directly on the floor or elevated platform. Because they are not restrained, the bulbs roll during store loading to completely fill the storage space. Bulk storage permits maximum utilisation of store space, and uniform aeration is easier to achieve than in stacks of bags or other rigid packaging. However, where bulk storage is to implemented, the retaining walls must be strengthened when storing larger quantities of bulbs, and arrangements need to be made for rebagging before subsequent marketing. It is also difficult to inspect bulbs regularly under these storage conditions. Loose bulk handling of onion is most suitable for large-scale operations where forced ventilation can be provided during long-term storage. Soft cultivars (which are also generally sweet) 'Vidalia Sweets' should not be stored in loose bulk because of their high susceptibility to compression and impact damage.

Onions can be packaged and stored in a variety of containers such as boxes, cartons, bags, bulk bins, pre-packs, plastic film bags, and stretch-wrapped trays. Packages typically contain 25 kg and above, especially for transporting crop from field to store and/or during storage. The same 25 kg bags or smaller bags may be used from store to market place. Decision on which type of packaging to use depends on crop size, length of storage and marketing requirements. A problem with packaging onions in boxes, net bags and bulk bins is that if they are too large, and airflow pattern tends to be around rather than through them. Under this condition, the respiration heat of the bulb results in a warm, humid environment in the centre of the package, which can result in decay or sprouting. To avoid these problems in large stores, the capital investment in packaging may be quite substantial.

Onion Bags

*S*acks and nets used for onion packaging fall into three groups: (i) general-purpose jute sacks, as used for many agricultural commodities, (ii) open-weave sacks of sisal-like fibre, (iii) open-mesh nets, normally of plastic materials and (iv) big bags, used alternatively to crates, containing up to 1000 kg . Jute sacks are readily available in most developing countries, but their disadvantages include: (i) generally too large - may contain 100 kg onions, hence difficult to handle and an increased risk of mechanical damage; (ii) bulbs are not visible through the fabric, and it is difficult to monitor condition during storage; (iii) there is some resistance to airflow if they are used in an aerated store; (iv) difficult to label effectively; and (v) recycled sacks may encourage spread of postharvest diseases.

Sisal sacks are made from sisal-like hard fibres and have an open weave, with thick threads spaced between about 10 and 15 cm apart. The rough nature of the fibre provides a sufficiently stable weave. These sacks are similar to jute sacks, but will allow limited visibility of the onions and impedance to airflow is less.

Open-mesh nets are the most widely used package for onions, and they are normally red or orange in colour. The slippery nature of plastics can result in the movement of the threads allowing large holes to open up. To overcome this problem, alternative nets are industrially produced to give fully stable mesh and stronger bag. The principal techniques include: (i)

using extruded net from high-density PVC, (ii) knitted (warp-knitted) and asymmetric construction, and (iii) special weave in which weft threads are double, and twisted. They are also slowly degraded by sunlight, and should not be left outdoors for long period before use. In comparison with the other types of bags, they offer several advantages, including: (i) light weight, small bulk when empty, (ii) usually available in 12.5 and 25 kg sizes, (iii) fairly good visibility of bulbs, (iv) excellent ventilation, (v) hygienic, (vi) easy closing (draw-string types only), (vii) and crop brand and marketing information may be printed around the middle of the bag for easy identification.

Rigid Packages

A range of rigid containers is used to package onions for transportation, marketing, and/or storage (Opara and Geyer, 1999). The principal rigid containers are trays (10-15 kg of onions each), boxes (up to 25 kg), and bulk bins (up to 1000 kg). These types of packaging enable segregation of onions into different cultivars or sources. Choice of packaging material is important as wooden bins, for example, are liable to termite attack, and weathering during off-season. Rigid containers are also expensive, need regular maintenance and a forklift is required for handling larger containers. Where rigid containers are used for onion storage, building design is simpler than that for large-scale loose bulk storage as reinforcement of retaining walls are not required to support the bulbs. Handling damage of bulbs during filling and emptying can be high, but damage is reduced during store loading and unloading operations in comparison with loose bulk handling and storage.

Stacking of containers must be carried out with care and to ensure that the ventilation air is forced through the containers of bulbs and not around them. One of the main advantages of rigid containers is that they facilitate regular inspection of produce, and when problems occur with the stack, the area affected is often limited to a few trays, boxes or bins which may be more easily isolated and removed than in loose bulk handling system.

Onion Pre-packs

Onions are commonly sold in retail outlets in pre-packs with a capacity of 0.5-1.5 kg. Pre-packing offers the following advantages over single bulbs in heaps or bags: (i) price can be attached to produce, (ii) the collation of a number of pieces into one unit of sale may promote sale of a larger quantity than would be purchased otherwise, (iii) provides a clean odourless unit for the customer to handle, and (iv) reduces time spent at the check-out. The use of weight/price labelling machines and bar-coding has reduced the need to pack to fixed nominal weights. During preparation for retail, the quantity of produce is measured by hand or machine and filled into the pack. Then the actual weight and price and/or bar-code are automatically calculated and printed on a label, which is attached to the package. This mechanised weighing and labelling system assists the packer in accurate record keeping and avoids losses due to inaccurate pack weights. The three main types of onion pre-packs are nets, plastic film bags, and stretch-wrapped trays

2.6 Bulk Storage

General Requirements

The objectives of onion storage are to extend the period of availability of crop, maintain optimum bulb quality and minimise losses from physical, physiological, and pathological agents. Bulbs selected for storage should be firm and the neck dry and thin. Discard thick-necked bulbs because they are most likely to have high moisture content than optimum for storage, and therefore would have short storage life. Skin colour should be typical of the cultivar. Microbial infections such as Aspergillus niger occur during production of onions but

these will only develop on the bulbs during storage where the storage environment is conducive for their growth. Prior to storage, crop must be cleaned and graded, and all damaged or diseased bulbs removed. Careful harvest and pre-storage treatments with minimal mechanical loads are important to achieve a long storage period. Both store room temperature, relative humidity, and atmospheric composition affect the length of storage that can be achieved. Several technology options are available for bulk storage of onions, including low-temperate storage, high-temperature storage, 'direct harvest' storage and the use of controlled atmosphere (CA) stores. The recommended storage conditions under these systems are summarised below.

Storage at Low Temperature

For successful low temperature storage, good ventilation and a low level humidity in the range of 70-75% is essential. To maintain good quality crop, the period of storage varies but may be up to 200 days. For maximum storage period and minimum losses bulbs should be fully mature at harvest, and dried until the 'neck' of the bulb is tight. For large-scale commercial storage, onions are usually stored under refrigeration and the most commonly recommended conditions are 0°C with 70-75% rh. Regular ventilation and monitoring of both temperature and relative humidity in the store are necessary to avoid significant fluctuations in environmental conditions. During the first few days of storage the fans should provide an adequate airflow, to remove water in the outer skins and to dry bruises. High air speed is needed for a period of up to 1 week, until the skin of the upper onion layers in the bulk rustles. Excessive humidity in-store will lead to the development of roots and promote rotting while higher temperatures will result in sprouting and promote development of pathological disorders such as Botrytis rots (Thompson, 1982) Bulbs freeze below -3°C and a range of storage temperatures and relative humidities have been recommended for safe storage of onions (Table 5). Spring (green) onions store best at about 0°C and very high humidity (95%) (Table 6). The maximum length of storage under these conditions varies from just a few days to about 3 weeks. Ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels without inducing condensation of water on the surface.

Table 5: Recommended refrigerated storage conditions for onion bulb

Temperature (°C)	Relative humidity (%)	Length of storage
-3-0	70-75	6 months
-3	85-90	5-7 months
-2	75-85	300 days
(-2) - (-0.6)	75-80	6 months&
-1-0	70-80	6-8 months
-0.6	78-81	6-7 months
0	75-85	6 months
0	65-75	-
0	70-75	20-24 weeks*
0	70-75	-
0	65-70	1-2 months#
0	65-70	6-8 months†
0	-	230 days
0	70-75 or 90-95	up to 120 days
0	80-85	30-35 weeks§
1-2	80-85	30-35 weeks¥
1	87	-
1.1	70-75	16-20 weeks‡
4	-	170 days
8	-	120 days
12	-	about 90 days
20	-	25 days

*= With 16.3% loss (red onion); #= Bermuda cultivar; †= Globe cultivar; ‡= With 14.2% loss (red onion); &= Superba cultivar; §= Optimum storage conditions, 7% maximum water loss before becoming unsaleable; ¥= Probable practical storage conditions, 7-10 days shelf-life (approx.) at 20°C after storage, 7% maximum water loss before becoming unsaleable. Compiled from (Thompson, 1996; Thompson, 1982).

Table 6: Recommended refrigerated storage conditions for Spring (green) onion.

Temperature (°C)	Relative humidity (%)	Length of storage
0	95-98	-
0	90-95	a few days
0	90-95	2 weeks
0	95-100	-
0-1	95-100	1-3 weeks

Source: (Thompson, 1982)

Onion Storage at High-temperature

Onions can be stored at high temperatures of over 25°C at a range of relative humidities (75-85%) which is necessary for minimising water loss. Storage at temperatures of 25-30°C has been shown to reduce sprouting and root growth compared to low-temperature storage (10-20°C). However, weight loss, desiccation of bulbs, and rots occurred at high temperatures,

making the system uneconomic for long periods of storage that is required for successful onion marketing (Thompson et al., 1972; Stow, 1975). In tropical climates, high-temperature storage of onions can be achieved under both ambient and heated storage conditions. Under these conditions, ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels.

'Direct Harvest' Storage

The need to cure onions can pose considerable challenges in situations where the climatic condition is unpredictable during the harvest period. To overcome these problems, the 'direct harvest system' has been developed and used extensively, particularly by growers in the UK, since the early 1980s. The bulbs are harvested while green, topped, loaded into store, dried and cured using well controlled ventilation system, and thereafter held in long-term low-temperature storage as required (Table 7). During stage I, removal of excessive surface moisture is achieved at high airflow rates, ignoring the rh of the air. Stage II is completed when the skins have been cured on the bulb. Adequate control of the storage condition at the various stages is critical to the success of this storage system in maintaining required bulb quality.

Table 7: Environmental regimes used during direct harvest storage system.

Stage	Duration	Temperature (°C)	Humidity (%)	Airflow rate ($m^3.s^{-1}.tonne^{-1}$)	Comments
I	3-5 days	30-32	-	0.12	Removal of surface water
II	20 days (approx.)	26 initially, slowly reduced to 15	65-75	0.048	Removal of surface moisture, drying and curing of the skins, and sealing; Completion indicated by rustling of skins when handled
III	As required	0-5	65-75	-	Minimise respiration, extended dormancy; Up to 10 months storage possible
IV	7 days (approx.)	Above dew point of air in grading shed	65-75	-	Bulb warming to avoid condensation of moisture during grading and reduce susceptibility to bruising; condensation on bulb would also reduce appearance quality if dust and dirt stick on bulb.

Source: (Brice et al., 1999)

CA Storage of Onions

CA is used in combination with cold storage to extend the storage life of onions. Recommended air composition and temperature regimes are summarised in Table 8. Spring onions generally tolerate higher CO_2 and O_2 levels than bulb onions, and the levels of CO_2 and O_2 combination required varies depending on the storage temperature (Table 9).

Commercial CA storage of onion bulbs is limited partly because of variable success and inconsistent effects on bulb quality. However, high carbon dioxide (0-5%) and low oxygen (1-3%) levels in combination with low temperature storage has been shown to reduce sprouting and root growth (SeaLand, 1991; Hardenburg et al., 1990). The combination of CA storage (5% CO_2, 3% O_2) and refrigerated storage (1°C) also resulted in 99% of the onion bulbs considered marketable after 7 months storage; however, 9% weight loss occurred (Smittle, 1989).

Onion response to CA storage varies among cultivars. Therefore, experiments should therefore be conducted under local conditions to determine the appropriate level of gas composition suitable for safe storage of local cultivars. CA storage generally increases the pungency of characteristic cultivars. For the 'Viladia Sweets' which are known for their sweetness and low pungency, the recommended storage conditions are (Smittle, 1989): 1 ºC, 70-80% rh, 3% O_2, 5% CO_2, 92% N_2, and ventilation rate of 5.m3.h-1.m3 of onions.

Table 8: Recommended controlled atmosphere composition for storage of onion bulbs

Carbon dioxide (%)	Oxygen (%)	Temperature(°C)
0	1-2	-
0	1-2	0-5
0-5	1-2	0-5
0-5	0-1	0-5
5	3	1
5	3	1
5	3	-
5	5	4-5
10	3	4-5

Source: (Thompson, 1996)

Table 9: Recommended controlled atmosphere composition for storage of Spring (green) onions

Carbon dioxide (%)	Oxygen (%)	Temperature (°C)	Comments
5	1	0	Stored for 6-8 weeks
0-5	2-3	0-5	Had only a slight effect
10-20	2-4	-	-
10-20	1-2	0-5°C	Had only a fair effect but was of limited commercial use

Source: (Thompson, 1996)

2.7 Processing

Onion bulbs are generally chopped into desired sizes and shapes using a knife. Many commercial devices are also available for chopping onions. In some food preparations, the onions are blended with other ingredients to produce the desired flavour.

3. Overall Losses

Estimated loss of total onion crop in developing countries is high and can reach 20-95% (Anon, 1978). Post-harvest losses of 16-35% have been reported (Steppe, 1976). Exact data on the nature and extent of these losses at each step in the postharvest chain is not readily available in the literature However, losses of over 9% has been reported for Spring onion between wholesale and retail (Amuttirantana and Passornsiri, 1992).

4. Pest Control

Onions are susceptible to pests and diseases during growth and postharvest handling. Weeds can also reduce yields and provide conducive environment for other pests and disease agents. The University of California Pest Management Guidelines (http://www.ipm.ucdavis.edu/PMG) provides specific information for onion and garlic pest management, including species and herbicide treatment (covering preplant and postplant stages). Onion thrips are common insect pests and the adults and larvae suck out juices from plants. For biological control, apply a dust of diatomaceous earth. Some lady beetles are predators of thrips. For chemical treatment, mix about 4 litres of water with Diazinon 25%EC, 2 tea spoon, or malathion 4% dust or 57%EC, 1 table spoon. Plants should be treated when thrips appear in numbers, and do not apply diazinon within 10 days or Malathion within 3 days prior to harvest.

5. Economic and Social Considerations

Although onions are important food sources in comparison with the other major root and tuber crops (cassava, yams, potatoes and edible aroids), they are part and parcel of human diet in both developed and developing countries. Due to their ability to grown in both tropical and temperate regions, the growing and handling of onions has received considerable attention in agricultural research and development. Despite the advancements in mechanical harvesting, curing and storage of onions, losses can be high for many small-holders and medium-scale farmers when lack access to improved techniques due to their limited financial resource. Improvements in hand harvesting and curing techniques can enhance the efficiency of small-scale farmers, particularly those who grow most of their crop to sale. These improvements must be targeted to improve to the welfare of rural farmers, particularly women and children who carry out most of the operations in subsistence farms.

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7. Annex - List of tables

Table 1: Global production and trade in dry onions

Table 2: Contents of major nutrients and vitamins in onion bulbs (*Allium cepa var. cepa*) and leaves (*Allium fistulosum*) per 100g edible portion.

Table 3: Summary of the Requirements for the International OECD Quality Standard

Table 4: Interpretation of the OECD International Quality Standard for Minimum Requirements for Onions (*Allium* cepa L.)

Table 5: Recommended refrigerated storage conditions for onion bulb

Table 6: Recommended refrigerated storage conditions for Spring (green) onion.

Table 7: Environmental regimes used during direct harvest storage system.

Table 8: Recommended controlled atmosphere composition for storage of onion bulbs

Table 9: Recommended controlled atmosphere composition for storage of Spring (green) onions