Post-harvest technology of spices : pre-treatments, curing, cleaning, grading and packing

J S PRUTHI
President, Carishma Food Consultancy Services, 376 DDA Flats Mansarovar Park, Shahdra, Delhi - 110 032

ABSTRACT

The post harvest technology of spices comprises of a whole gamut of operations such as pretreatments, chemical treatments, curing and similar operations, drying, cleaning, sorting, grading and packing. These aspects are briefly covered in this review. Wherever applicable the problems involved and the relative advantages and disadvantages of the various processes are indicated.

Key words: spices, post-harvest technology, curing, grading, packaging, processing.

CONTENTS

1. Introduction

Spices, like all other agricultural commodities, invariably contain high moisture (55-85%) at the time of harvest, which must be brought down to 8-12%. Further more, spices vary considerably in shape, texture, size, colour, etc. as they may be fruits, berries, barks, seeds, leaves, rhizomes, roots, unopened flower buds (cloves) and other floral parts (saffron). Hence their pre-treatments, curing, cleaning and methods of processing also vary considerably. During their post-harvest processing, they are subjected to different types of unit operations such as washing, peeling, curing, drying, cleaning, grading, and packaging, until they are ready for the consumer or for the market. Such post-harvest processing technology should ensure proper conservation of the basic qualities of spices for which they are valued - aroma, flavour, pungency or bite, colour, etc.

It is the prime requisite that all spices be harvested at the correct stage of maturity without much physical damage, after which they are processed properly for the market. In most cases, they are sun dried at the farm and transported to an appropriate centre for further processing. Processing operations, of course, vary with the individual spices concerned (Pruthi 1980a, 1991 a, b, c; Purseglove 1981). These are briefly discussed here along with the problems of post-harvest technology of spices.

2.0 Pre-treatments

Post-harvest treatments of black pepper as practiced in different parts of the world have been reviewed (Larcher 1967; Pruthi 1991a). The technique of keeping freshly harvested pepper corms for 48 hours in the shade is the best treatment for the manual separation of berries and the highest yield of essential oil content (4.96% on a dry-weight basis) and piperine content (Larcher 1967). The prolonged boiling-water treatment is not very useful, as it alters the chemical composition of the oil, though it lowers microbial load considerably and the product is hygienic.

2.1 Washing

Root and rhizome spices such as angelica, calamus, ginger and turmeric, which are dug out of the soil, need washing to remove the adhering mud and dirt. Pressure-water washing may be possible, wherever facilities are available. Reduction in the microbial load will also be influenced by the efficacy of this operation.

2.2 Peeling

Almost all spices are dried whole (without peeling), with the exceptions of ginger, onion and garlic. The skin of the ginger rhizomes constitutes a barrier to evaporation or transportation of moisture from within, hence a prerequisite for efficient drying of ginger is peeling; hand-peeling with special scraping knives is resorted to. Partial mechanical peeling of ginger has been tried with abrasive machines for 60 seconds, which is equivalent to hand-scraping with respect to loss of volatile oil, time of drying, and peeling loss of 10 to 20 %. The timing of abrasive peeling is rather critical, and care should be taken; otherwise it results in heavy losses. This is also another method of reducing the time of drying, but the conventional trade will have to be educated and assured about its economy and the negligible chances of adulteration in the sliced and dried product (Kuppuswamy 1974; Natarajan *et al* 1972).

Cinnamon and cassia barks are peeled off the tree branches (2 to 3.5 cm thick) with the help of special curved knives, cut into convenient sizes before they are cured, and dried as quills, quillings, featherings and chips (Pruthi 1980; Pruthi, Varkey & Bhat 1987).

In nutmeg, the outer rind is removed, exposing scarlet mace, which is gently detached and dried in partial shade. Seed is also sun-dried.

2.3 Pricking

Pricking the skin of chillies longitudinally helps to reduce the time of drying (Laul *et al* 1970) and helps in better retention of colour and overall quality. Same applies to the capsicums and red paprika.

2.4 Blanching

Blanching is almost universally practiced in vegetable drying and dehydration chiefly for the inactivation of enzymes, but exceptions are celery, garlic, onion and parsley, which are valued primarily for their specific flavours, since blanching destroys the very enzymes involved in the generation of their respective flavours. In chillies and ginger also, blanching is not desirable.

However, blanching or simmering is a commercial practice in the case of turmeric, particularly in the presence of a small quantity of alkali (Desikachar, Srinivasan & Subramanyam 1959) as described under curing of turmeric (para 2.6.4).

For the preparation of good quality black pepper, a simple blanching process which can be easily adopted by even the small and marginal pepper growers, has been developed in India by CFTRI. This involves:

"The mature greenish yellow, pepper spikes are despiked after harvest. The pepper berries are cleaned by winnowing, transferred to perforated aluminium vessel or even bamboo basket and dipped in boiling water for a minute, drained and spread out on a clean cement floor or bamboo mat for sun-drying".

2.4.1 Advantages of blanching of pepper

i) The blanched berries require only 2 days for drying in the sun. Thus, a great saving in time.
ii) The dry pepper has an attractive uniform black colour.
iii) Blanching minimises microbial contamination and thus gives a more hygienic product.

Likewise, for the preparation of dried dehydrated green pepper as well as white pepper, hot water treatment is given in several countries.

2.5 Chemical treatments

Many types of chemical treatments such as alkali treatments, antioxidant treatment, bleaching by liming treatment, sulphuring by sulphur fumes, and sulphitation or treatment with SO_2 or hydrogen peroxide are employed by the industry for different spices - for example, alkali treatment for cardamom, liming or bleaching of ginger, bleaching of cardamom by sulphuring or sulphitation, and curing of turmeric with appropriate chemical solutions, as discussed briefly below (Desikachar, Srinivasan & Subramanyam 1959).

2.5.1 Alkali treatment

The attractive green colour of cardamom, which is due to chlorophyll, can be stabilized to a great extent by steeping the cardamom in 2% sodium carbonate solution for 10 minutes. Alkali treatment has also been found useful in drying of chillies, particularly in conjunction with olive oil (Laul *et al* 1970). Lime treatment is used for bleaching of ginger, as will be discussed briefly later under para 2.5.3.

2.5.2 Antioxidant treatment

The attractive red colour of capsicums or chillies, which is due mostly to carotenoids (notably capsanthin, capsorubin, etc.) is stabilized to a great extent by treatment with a suitable antioxidant (Van Bharicum & Martin 1951; Lease & Lease 1956). Several scientists have also studied the effects of other factors such as initial composition, light, air temperature, condition (whole or ground), harvesting practices, and pre-drying treatments on the retention of colour in capsicum during drying and storage.

2.5.3 Bleaching of cardamom and ginger

(a) Cardamom - There is some demand for bleached cardamom, though mainly it is sold with its natural green colour. In fact, cardamom capsules that do not have uniform green colour are less valuable, and such capsules are put through a bleaching process to produce a uniform colour. Bleaching powder, sulphur dioxide, or hydrogen peroxide is generally used for bleaching. Sulphur dioxide is obtained either through burning sulphur or by wet sulphitation - that is steeping in dilute solutions of water soluble salts of SO_2. Bleaching is also done by hydrogen peroxide. Bleaching has been developed into a highly scientific and paying profession in Sweden. In South India too (West Coast and Karnataka State), bleaching of cardamom is carried out. However, SO_2 - bleached cardamom samples have shown variations in SO_2 content from 20 ppm to 3 ppm. There is, therefore, need for standardization of the method of sulphuring or sulphitation.

(b) Ginger - The peeled ginger rhizomes are washed and kept steeped in plain water for 2 to 3 hours. Thereafter, they are taken out and steeped in about 1.5 to 2.0% lime (CaO) solution for about 6 hours. They are then drained and sun-dried on mats, barbecues, or on a clean cement floor. This liming or bleaching of ginger not only improves its colour, but also helps to preserve it better. Care should be taken to use the best quality slaked lime in order to get better whiteness (Rodriguez 1971). Besides, liming is reported to retard insect infestation.

The application of these chemicals requires proper control, especially in the bleaching of cardamom and ginger. It is necessary to know the extent of SO_2 picked up by cardamom during bleaching. Bleaching also involves rehydration, and therefore careful control of the final moisture content is essential for prevention of insect infestation during storage. It is thus necessary to prescribe scientifically controlled procedures to obtain uniformity in product batches and at the same time to safeguard against the indiscriminate use of such chemicals.

2.6 Curing and other treatments

Different spices such as cinnamon and cassia, garlic, saffron, turmeric and vanilla beans are cured by different techniques in order to generate the characteristic aroma or flavour for which they are valued.

2.6.1 Cinnamon and cassia - peeling and curing

The peeled slips (bark) from cinnamon and cassia branches are gathered and packed one above the other with their concave and convex surfaces in juxtaposition until the packings measure about 20 to 30 cm wide and 30 to 45 cm long. These slips are piled up within enclosures of sticks and wrapped up in mats. The packs are kept overnight in that condition for curing or for allowing so-called 'fermentation'. Actually no real fermentation process develops. A little softening of the bark does occur, with the result that the peels become more easily pliable for the subsequent piping operation or the removal of the epidermis and the green cortex.

2.6.2 Smoke-curing of garlic

The better quality of smoked foods is due to (1) partial dehydration (2) incorporation of natural antioxidants (3) impregnation of antiseptic constituents (4) effect of heat on micro-organisms and (5) improvement in organoleptic quality. The benefits of the smoking process of garlic and physicochemical changes during storage of smoke-cured garlic have also been reported.

2.6.3 Curing of saffron

The value of saffron depends heavily on the methods by which the stigmas are processed. In Spain, where the process is called 'toasting', the stigmas are placed in sieves in layers 2-3 cm thick. These sieves are placed 15 cm above an almost spent fire for drying. By stacking them and by changing their order or position, the product is carefully dried. Great care must be taken that the stigmas are protected against dampness as well as light, because light bleaches saffron to a dull yellow colour. Drying in the sun or over smoke also bleaches the saffron or changes its colour (Katyal 1967).

2.6.4 Curing of turmeric

Curing of raw turmeric rhizomes and fingers freshly dug out of the earth is essential for the development of the attractive yellow colour (mostly due to curcumin) and aroma; without curing, it lacks both. Curing begins 3 or 4 days after harvesting. The mother rhizomes and fingers are separated by hand, if necessary, the former are kept for seed purposes and the latter are cured for marketing by the following techniques.

(a) *Conventional technique* - The fingers and bulbs are boiled in water until a froth comes out and white fumes start to appear, giving the typical turmeric aroma. The fingers and bulbs become softer and yield when pressed between the fingers. At this stage, they are removed from the boiling water, drained properly, coloured artificially if necessary and dried in the sun for 10 to 15 days, after which they are polished to remove any adhering rootlets and scales.

The quality of the final product, including its colour and aroma depends largely on the correctness of curing, but according to another report, the curing quality of turmeric is mostly a varietal character, although other factors such as high moisture content, maturity and seasonal conditions influence the percentage of recovery (the ratio of the cured and dried turmeric to raw turmeric) to some extent. It is further reported that short-duration Kasturi turmeric *(Curcuma aromatica)* types recorded the highest percentage (24 to 26%), medium duration Kesari turmeric *(C. longa)* types gave the lowest values (14 to 20%), and long-duration *(C. longa)* types showed medium values (21 to 24%). Mother rhizomes recorded a higher percentage than the corresponding figures. The curing percentage increased with increasing maturity of the rhizomes. Raw rhizomes with higher initial moisture content yielded both a poor-quality product and a lower curing percentage.

(b) Improved scientific method - A new scientific method of curing turmeric has been developed at Central Food Technological Research Institute (CFTRI) Mysore, according to which, the washed raw tubers are boiled in dilute lime water, sodium carbonate, or sodium bicarbonate solution instead of in water. For imparting the characteristic yellow colour to the tubers, a solution containing 20 g of sodium bisulphate and 20g of concentrated hydrochloric acid per 150 pounds (or about 70kg) of boiled tubers has been recommended (Desikachar, Srinivasan & Subrahmanyam 1959) in place of the Chemichrome solution used earlier in the country practice, which by now is no longer popular and has been dispensed with.

2.6.5 Curing of vanilla beans or pods

At the time of harvest, in the vanilla fruit or pods, the normal aromatic components forming the characteristic vanilla flavour do not exist in their final form, but appear only following a curing (fermentation) process involving enzymatic actions on glucosides, the most important of which is glucovanillin, which produces vanillin (the main aromatic component of vanilla) and sugar as a result of the action of B-glucosidase. Similarly, aldehydes, protocatechoic acid, benzoic and vanillic acids, anisic alcohol, etc. are also formed. These different compounds impart subtlety to the fragrance of natural vanillin enabling it to be distinguished from synthetic vanillin (Theodose 1972).

Different curing methods are used in different producing countries such as Madagascar, Mexico, Tahiti, Guadeloupe, Bourbone Islands and India. All these methods of fermentation are characterised by the following different stages:

i) Cessation of the vegetative life of the bean to allow the onset of enzymatic reactions.

ii) Raising of the temperature to promote this action and to stimulate at first quite rapid drying, thereby preventing the appearance of harmful fermentation.

iii) Slower drying followed by the production of different fragrance components.

iv) Conditioning of the product, during which the operations geared to commercial presentation and to obtain good preservation are carried out.

Theodose (1972) has systematically reviewed and discussed these methods and, on the basis of his own research, has described an improved method that cuts labour by 80% and further more, gives a 6 to 8 % higher yield with higher vanillin content and better quality. The improved method consists in sorting or grading, scalding or blanching, autoclaving, loading and mechanically drying in a tunnel dryer, followed by drying in the shade.

The following new improvement is claimed to give excellent results:

After scalding and autoclaving, the vanilla beans are chopped into 2 or 3 cm pieces. This leads to an acceleration of the oxidative and enzymatic reactions.

The 'cuts' are put through the dryer at a temperature of 65°C each day. As soon as they come out, they are put into an isothermal chest for the next 24 hours, their temperature being maintained at around 50 °C. These operations are repeated for 12 days, after which a product containing 20 to 25 % moisture is obtained, with a yield of about 4.5 to 1.0. The transfer to the isothermal chests after the tunnel drying is vital, in addition to accelerating the enzymatic action, it allows the various cuts to equilibrate their moisture content; otherwise, with an acceleration of drying, a product with poorly developed aroma and a smell almost of prunus is obtained. The only drawback of the method is its likely social repercussion, as it eliminates 80% of the labour required in the conventional techniques. Otherwise, this new process is capable of producing three tons of vanilla per day, and thus it constitutes a significant breakthrough, especially for vanilla-producing countries with heavy rainfall. Plans for installations and comparative costs of production by different techniques have been worked out and discussed (Theodose 1972). After conducting some trials in India on different curing methods, several Indian workers recommended the Mexican process of alternatively sweating and drying vanilla according to which the shrivelled vanilla beans, 3 to 4 days after harvest, are immersed in hot water (60°C) for one minute and spread out on woollen blankets for sun drying. When the beans become too hot to hold in the hand, the blanket is folded over them and kept there for the rest of the day. At night, the beazns are kept in 'sweating boxes' lined with blankets. The next day, the beans are again put on the blankets and dried in the sun. The process is repeated for about 8 to 10 days, depending on weather conditions. By this time, the beans have lost most of their moisture, acquire a dark chocolate brown colour, and develop the typical vanilla aroma (Kannan & Pillai 1966; Nair & Mathew 1969).

However, the Mexican process requires a series of sheds or buildings for 'sunnings' and 'sweatings' and 'mahogany sweating boxes' or 'aging boxes'. The total process takes about 5 to 6 months, including aging. Finally, the beans are graded, bundled and packed in special tins lined with waxed paper.

2.7 Other pre-treatments are 'pricking' and 'cheeking' of chillies briefly described under sun-drying of chillies later.

3. Drying of spices

3.1 Sun drying of spices

Sun drying of cardamom treated with 2% sodium carbonate in a special type of glass chamber, which could exclude rain and mist and at the same time provide necessary ventilation, yielded satisfactory product (Vijayan 1924). The product was compared with that obtained by the conventional techniques employing smokeless flues and direct sun drying. No significant difference was found among the three methods of drying in spite of the usual alkali treatment. Loss of moisture was also slightly more in flue drying. A major saving in labour could be obtained by using the solar drying technique. However, there is need for development of still better treatment for the preservation of the natural green colour.

3.1.2 Sun drying of chillies

In Japan, sun drying of chillies is followed by mechanical drying, dressing, and again sun drying before packing. The entire stem or plant with the fruits is cut and hung from bars and then exposed to the sun for partial sun drying. After the removal of 80% moisture, the parts are further dried in a dryer to the critical moisture level. The dried parts are removed with the help of a dressing machine and finally again dried in the sun before packing. This efficient combination of sun drying and dehydration may work well in such cases. The main problem is the heterogeneity in the product with special reference to size, colour and quality. Grading helps in getting better results. Improved agronomic practices are also required to get a more uniform product at picking time.

Sun drying of chillies has also been studied in some detail in India. Whole chillies spread on perforated rectangular aluminium trays (@5kg/ m^2) took about 15 days to dry at a room temperature of 20 to 25°C and relative humidity of 34 to 50 %. Pricking the chillies longitudinally reduced the drying time to 12 days, and blanching reduced it to 7 days. In the case of checking, the drying time was 7 days after dipping in 2.5% potassium carbonate solution, and it was further reduced to 6 days in the presence of deodorized olive oil (Laul *et al* 1970).

3.1.3 Sun drying of garlic

The author and his associates have observed that in sun drying of garlic (flaked), the losses in allyl sulphide, total sulphur, anti-bacterial activity and aroma were the highest compared with losses in four different methods of dehydration (artificial drying). They, therefore, recommend efficient mechanical drying (Pruthi 1959).

3.1.4 Sun drying of ginger

In the author's experiments, hand-peeled and abrasive-peeled ginger lots with and without liming treatment were dried in the sun on raised platforms, which yield satisfactory products (bleached and unbleached ginger) in 7 to 9 days with a final moisture content of 7.8 to 8.8%.

3.1.5 Sun drying of pimento or allspice

At present, sun drying of Jamaican pimento or allspice berries is done on a concrete barbeque. Because of frequent shifting of the berries in and out of the sheds during rainy days, many berries break. Hence, mechanical drying is preferable, and it is also more economical than sun drying (Breag 1972).

3.1.6 Sun drying of other spices

Saffron discolours during sun drying (Katyal 1967). Photosensitive spices like cardamom, and to some extent chillies and turmeric, bleach in the sun owing to the oxidation of chlorophyll and carotenoids naturally present in them. During the rainy season, however, it is essential to resort to mechanical or artificial drying, which is briefly discussed below.

3.2 Mechanical drying

In order to avoid dependence on the vagaries of weather and also to reduce microbial contamination, natural convection dryers or forced-draft dryers can advantageously be used to get a better quality product. An air temperature of 60°C to 70°C gives a drying time of about 5 to 9 hours, depending on the commodity, particularly size and method of drying (Ramanathan and Rao 1974).

3.2.1 Factors affecting quality of dehydrated product

The quality of the dehydrated product is affected by a number of factors, including the quality or nature of the raw material, its method of preparation or processing treatments, the density of loading, the time, the temperature, and the method of drying or dehydration (Pruthi, Varkey & Bhat 1987). Of these factors, the temperature of the air used during dehydration greatly affects not only the time required for dehydration, but also the quality of the finished product. In order to secure large capacity and minimum operating costs, it is essential to use the highest temperature that will not materially injure the product. The optimum drying temperature and also the critical temperature of a product vary with nature of the product and its moisture content (Pruthi, 1980; Pruthi, Varkey & Bhat 1987).

(a) Critical temperature of dehydration: The critical temperature is defined as the temperature at which a nearly dry product is seriously injured when exposed for a certain period of time. At temperatures above the critical temperature, the dried product is likely to scorch, the sugars present are likely to caramelize, and the colour, flavour and aroma of the product are likely to be adversely-affected. To determine precisely the critical temperature of a product, the stability of its most desirable character(s) is followed up during heating at different temperatures.

Based on the data on the retention of anti-bacterial activity, allicin, allyl sulphide, colour and flavour in fresh and dried garlic flakes under different temperatures of dehydration from 30° to 70°, the critical temperature for dehydration of garlic was found to be 60° (Pruthi, Varkey & Bhat 1967). Pink discolouration in ginger from some areas like Assam was observed when it was heated beyond the critical temperature of 60°C. Work carried out in Australia has shown that 135°F is the highest temperature at which ginger for the spice market should be dehydrated, but if the ginger is to be used for extraction purposes, then temperatures up to 180°F are satisfactory (Richardson 1966). On the other hand, a perceptible darkening of ginger at temperatures above 60°C (140°F) has also been reported. There was no significant difference in the colour of samples dried at temperatures between 50°C and 60°C, indicating thereby that the critical temperature of ginger was 60°C (Natarajan *et al* 1972; Raina, Testia & Pruthi 1978).

Reports on the critical temperature of dehydration for chillies are rather conflicting. According to the source, the critical temperature for the dehydration of chillies is 46°C. In the author's view, 46°C is too low a temperature for economic dehydration. It takes 40 to 42 hours for the chillies to dry at this temperature in an ovan, and even with optimal air-flow the drying time is 26 to 28 hours (Kuppuswamy 1978). There is no appreciable darkening of chillies at temperatures up to 140 to 150°F. These observations are in line with the findings reported from the South Carolina Experiment Station, USA (Lease & Lease 1956).

(b) Methods of dehydration - The method of drying or dehydration is another important factor affecting the quality of a dehydrated product. Natural convection dryers forced-draft dryers can advantageously be used. This author and his associates (Pruthi, Varkey & Bhat 1987) studied the comparative effects of four mechanical methods of dehydration -

namely, hot-air drying by cross-flow or by through-flow separately, freeze drying, and vaccum-shelf drying versus sun drying on allyl sulphide, total sulphur, volatile reducing substances, anti-bacterial activity, colour and flavour of garlic and recommended through-flow dehydration for reasons of economics and quality.

For further drying of sun-dried black pepper, some of the progressive traders have installed cascade-type dryers using kerosene oil or gas as fuel. The moisture in the partially sun dried black pepper is brought down from 25% to within 10% in two stages in a countercurrent hot-air flow system. Pepper is introduced at the top, while hot air is introduced from the bottom. The reason for drying in two phases is that in the first drying, the surface of the pepper dries quite fast, but the moisture from within the core requires some time to diffuse out to the surface. Thus, after one pass, the pepper is stored for 24 to 28 hours, after which it is dried again as above down to 10% moisture.

The author has also seen the working of a mechanical dryer imported from Holland, in which 30 to 40 tons of pepper can be dried per 8 hour shift. It has proved to be more economical than sun drying, with the added advantage of better retention of quality. It also has a winnowing facility, but it has one social repercussion because of the drastic cut it would bring in human labour normally engaged for sun-drying operations.

(c) Other factors - Several other factors, such as the method of preparation, pretreatments like sulphuring, sulphitation, or treatment with antioxidants (in chillies) or other chemicals, and density of loading affect the quality of the finished product, as discussed by this author and his associates (Pruthi, Varkey & Bhat 1987) in standard textbooks on the dehydration of foods.

3.2.2 Dehydration of cardamom

For drying cardamom in shade, a natural convection drying system is used in two ways. In large plantations, drying is done in an enclosed room in which the capsules are heated by a system of pipes running along the length and height of the room, through which hot air of flues are passed from an external furnace. The cardamom placed on the racks inside the heated room gets dried out slowly. In small holdings, cardamom is dried on open platform heated from below and sheltered by a roof open on all sides. Sometimes., drying is also done on beaten ground or on a mat in the sun, but colour preservation is better with the above two methods. The technique of drying cardamom capsules in a heated chamber, along with the precautions to be observed has been described in some detail (Abraham 1965). Great care is to be exercised in controlling the temperature of drying as well as the drying rate. The dry-bulb temperature should not exceed 130° to 135°F in the stove. Drying should not be too rapid. At no time during the drying process should the cardamom be exposed to strong light, which bleaches out the green colour.

There is scope for improving the performance of the existing stoves by providing ventilators or exhaust fans at the top near the roof to facilitate the occasional removal of the air loaded with high moisture in the initial stages. Mechanical drying under controlled conditions is possible wherever electricity is available. Recently, a number of progressive planters in India have tried cross-flow dryers with success.

3.2.3 Dehydration of garlic

The author and associates conducted a series of studies on several factors influencing the quality of the final product, including method of preparation, pretreatments such as sulphuring and sulphitation, density of loading and spraying of garlic with antioxidants. The optimum tray load was found to be 1/2/ ft.; 1-2 kg. per tray of 16x32 inches (Pruthi, Varkey & Bhat 1987). Both sulphuring and sulphitation of garlic prior to through-flow dehydration improved the colour of the product, but they significantly reduced its flavour and completely destroyed antibacterial activity. Hence, sulphuring and sulphitation of garlic are unnecessary. Application of ascorbic acid also had no beneficial effect on the retention of flavour and antibacterial activity. In fact, it appeared to enhance browning during dehydration (Pruthi, Varkey & Bhat 1987).

3.2.4 Dehydration of ginger

In Australia ((Sharpnell 1967), the rotary dryer appears to be preferred for ginger dehydration because of lower labour costs. However, unless the ginger is sliced fairly thin, its dehydration is essentially a slow process. It is controlled for the most part by moisture diffusion, which is not hastened by agitation, with the result that the extra power consumption involved in working the rotary dryer for long periods is not justified (Kuppuswamy 1974, Natarajan *et al* 1972). The rotary dryer is not suitable for sliced ginger, since the wet material packed like sawdust forms an impermeable mass through which the air cannot penetrate (Sharpnell 1967). Even with the development of newer drying techniques, most vegetables (including spices) in a whole range of shapes and sizes are still dried on belts or trays - the simplest and the most economical method of dehydration. In India using a cross-flow dryer, it took only 5-6 hours to dry sliced, scraped ginger, as compared with 16 to 18 hours for dehydration of scraped, whole ginger (Raina, Teotia & Pruthi 1978).

3.2.5 Dehydration of onions

Dehydrated onion is produced by removing about 95% of the original moisture - that is, it is dried down to about 5% moisture - from peeled, derooted, and destemmed sliced onions. This author studied the batch dehydration of onion and packaging and storage of onion powder (Pruthi and Lal 1966). A novel continuous process for the dehydration of onion and garlic has been developed (Havinghorst 1955).

3.2.6 Dehydration of pimento berries and vanilla beans

The precise conditions for mechanical drying of pimento berries have been determined (Breag *et al* 1972). On the basis of evaluations of drying rates conducted both in London and in Jamaica, GC patterns and trade assessment, these authors concluded that green pimento berries could be artificially dried at an air-flow rate between 25 and 30 cm per second and a drying temperature of 70° to 75°C. This is more economical than sun drying, with an acceptable brown colour and appearance and without significant loss of oil. It was also found that periods of up to 2 days of fermentation facilitate the drying process. An indirectly oil-fired tray dryer for the average-sized pimento estate has been recommended (Larcher 1967).

The economic feasibility of an improved process of mechanical (tunnel) drying of cut pieces of vanilla beans, which reduces labour costs by 80% and is more efficient and convenient than sun drying, has been developed (Theodose 1972).

4.0 Cleaning, sorting and grading

Before packing, the dried seed spices are cleaned to get rid of extraneous matter such as dirt, grit, stones, stalks and leaves and also graded. Pneumatic separators equipped with magnetic separators are used to remove debris, their operation is based on the relative specific gravity of the particles. Magnetic separators are used to remove metallic contamination such as iron filings and stray nails. A combination of air classification and vibratory conveying, using inclined docks, is very efficient for destoning of spices. These units are fast, thorough in cleaning, compact, easy to install and require minimum of maintenance (Ramanathan & Rao 1974).

On a small scale, the dried spices are generally cleaned manually by winnowing or by use of blowers, etc., so that the heavier and bolder berries of pepper separate out from the dust, stalk and pinheads, which, being lighter, are blown away.

4.1 Mechanical cleaners-cum-graders

In well-known spice processing houses, pepper is cleaned and graded with the help of a multiple-sieve-cum-air-classifier type of machine whereby the following fractions are conveniently and quickly obtained: dust, stalks, pinheads, hollows, immature pepper, ripe pepper and extra-bold pepper. The separated pepper is then washed and dried in order to make it free of any adhering fungus and other extraneous matter. Alternatively, mechanical brushing between two rotating brushes can be used both to clean the pepper and to impart a nice shine to it. To sum up, the above techniques of processing of pepper, technically, consists of four steps - (1) drying, (2) separation of various fractions, (3) size segregation or grading and (4) physical cleaning - and finally packaging. It should be possible to cover the first four steps in one operation by using a pneumatic conveyer-cum-dryer with an arrangement for trapping the different cuts or segregations at different points or stages (Mariwala 1970).

Such mechanical cleaners-cum-graders should be installed near the producing areas or in the assembling or regulated markets so that only properly cleaned and graded spices are offered for auction.. Likewise, destoners, air classifiers, gravity separators, colour graders, and sieve graders of proper capacity should be installed for the benefit of the growers, sellers and buyers.

A single mechanical machine composed of clippers, air classifiers, polisher, specific gravity or size grader and inspection table, with a capacity of 3 to 5 tons of seed spices per shift of 8 hours, is available and is being used in some exporting and importing countries. Mechanical size graders of different capacities for onions and garlic are already in use, and their greater use should be encouraged in spice producing countries (Pruthi 1980).

4.2 Cleaning equipments

There are about seven types of cleaning equipments available in the USA (Table 1) and other developed countries. They are listed in Table 2, suggesting different types of equipments for the removal of extraneous matter like dead insects, rodent excreta, other excreta (birds, etc.), defiled insects and other inorganic extraneous matter (everything foreign to the spice itself) and include stones, dirt, wire, string, stems, sticks, non-toxic foreign seeds, etc. from as many as 31 spices and condiments, seeds, herbs or leafy spices.

Of the seven cleaning equipments suggested, the aspirator and magnetic separators are used virtually for all the spices. The capacity requirement would seem to depend on the individual spices for which they are required (Table 1). It thus depends on their nature, bulk-density, particle size, etc. However, the following capacities (plus/minus 10%) would seem appropriate (Table 1).

Table 1. Types of cleaning equipments for spices, seeds, herbs and their working capacities

S.No.	Type of equipment	Capacity	
		Mt/day*	Kg/hour
1.	Rotary knife cutter	1.36	85
2.	Destoners	19.00	1200
3.	Air table	5.80	365
4.	Cylinder separator	1.70	110
5.	Plain sifter	1.60	105
6.	Spiral gravity separator	10.40	650
7.	Air screen separator	13.50	845

* A day comprises 2 shifts of 8 hours each.

4.3 Grading of spices

Well-defined trade grades and quality characteristics of major spices such as pepper, cardamom, ginger, chillies and turmeric, ground spices, curry powder and eighteen other minor spices have been established by the Department of Marketing and Inspection, Govt. of India (1982, 1987) according to the preshipment inspection scheme under the Compulsory Quality Control Act. These grade standards are being implemented rigorously under the Agmark Grading Scheme particularly for exporters from India. ISO (International Standard Organization) has also prescribed commercial grades/types of several spices.

4.4 Advantages of grading of spices

(1) Grading and standardization play an important role in marketing of agricultural products including spices. It is a well known fact that spices exhibit wide variations in quality due to a number of factors such as the varietal differences, varying agro-climatic conditions of growth, different methods of processing and preparation for market, etc. Further, spices being perishable/semi-perishable by nature, changes in quality do occur during storage, also the quality requirements for different end uses of the same commodity also differ considerably. Obviously, therefore, grading and stan-

Table 2. Cleaning equipments for unprocessed spices, seeds and herbs

Names of Spices	SUGGESTED EQUIPMENTS FOR THE REMOVAL OF:				
Seeds, Herbs	Whole insects dead	Rodent excreta	Other excreta	Defiled insects	Extraneous matter
1. All spice (Pimento)	Spiral gravity separator	Spiral gravity separator	Spiral gravity separator	Rotary knife cutter & air screen separator	Spiral gravity separator
2. Aniseed	Vacuum gravity separator (A.T.)	Vacuum gravity separator (Air table)	Vacuum gravity separator	-	Vacuum gravity separator
3. Basil	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	-	Vacuum gravity separator and destoner
4. Caraway Seed	Vacuum gravity separator (Air table)	Vacuum gravity separator (Air table)	Vacuum gravity separator (Air table)	-	Vacuum gravity separator (Air table)
5. Cardamom	Air screen separator	Air screen separator	Air screen separator	Aspirator and air screen separator	Air screen separator and destoner
6. Cassia	-do-	-do-	-do-	-do-	-do-
7. Cinnamon	-do-	-do-	-do-	-do-	-do-
8. Celery Seed	Vacuum gravity separator (Air table)	Vacuum gravity separator (Air table)	Vacuum gravity separator (Air table)	-	Vacuum gravity separator (Air table)
9. Chillies	Air screen separator	Air screen separator	Air screen separator	Rotary knife cutter and screen separator	Air screen cutter and separator
10. Cloves	-do-	-do-	-do-	-do-	-do-

11. Coriander seed	Spiral gravity separator	Spiral gravity separator	Spiral gravity separator	Rotary knife cutter and screen separator	Spiral gravity separator
12. Cumin seed	Vacuum gravity separator	Vacuum gravity separator	Vacuum gravity separator	-	Vacuum gravity separator
13. Dill seed	-do-	-do-	-do-		-do-
14. Fennel seed	-do-	-do-	-do-		Vacuum gravity separator and destoner
15. Fenugreek	-do-	-do-	-do-		Vacuum gravity separator and destoner
16. Ginger (whole and splits)	Air screen separator	Air screen separator	Air screen separator	Rotary knife cutter and screen separator	Rotary knife cutter and air screen separator and destoner
17. Laurel leaves and Bay leaves	Plain sifter	Plain sifter	Plain sifter	Rotary knife cutter and Plain sifter	Rotary knife cutter Plain sifter and destoner
18. Mace	Air screen sseparator	Air screen separator	Air screen separator	Rotary knife cutter and screen separator	Air screen separator
19. Marjoram	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	-	Cylinder separator (indent) and separator
20a. Nutmeg (broken)	Air screen Separator	Air screen separator	Air screen separator	-	Air screen separator
20b. Nutmeg (whole)	Plain sifter	Plain sifter	Plain sifter	Rotary knife cutter and air screen separator	Air screen separator

21.	Oregano	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	Cylinder separator (indent) and destoner	-	Cylinder separator (indent) and separator
22.	Parsley	Air screen separator	Air screen separator	Air screen separator	-	Air screen separator and destoner
23.	Black pepper	Special gravity separator	Special gravity separator	Special gravity separator	-	Air screen separator and destoner
24.	White pepper	-do-	-do-	-do-	-	-do-
25.	Poppy seed	Vacuum gravity separator	Vacuum gravity separator	Vacuum gravity separator	-	Vacuum gravity separator and destoner
26.	Rosemary leaves	Plain sifter	Plain sifter	Plain sifter	-	Plain sifter and destoner
27.	Sage	Air screen separator	Air screen separator	Air screen separator	-	Air screen separator and destoner
28.	Savory	Plain sifter	Plain sifter	-do-	-	-do-
29.	Tarragon	Plain sifter	Plain sifter	-do-	-	-do-
30.	Thyme	Vacuum gravity separator	Vacuum gravity separator	Vacuum gravity separator	-	Vacuum gravity separator and destoner
31.	Turmeric	Plain sifter	Plain sifter	Air screen separator	Rotary knife cutter and air screen separator and destoner	Rotary knife cutter and air screen separator and destoner

dardization become the essential prerequisite for ensuring the quality of product to the consumer.

(2) Grading also helps the spice producer in realizing prices commensurate with the quality of the produce.

(3) Grading and standardization no doubt make a major contribution to the improvement of marketing system of spices by establishing a common international trade language. Under an efficiently managed grading and standardization programme, transactions can take place on the basis of recognised grade standards rather than on samples which often lead to disputes.

(4) The time-consuming and wasteful practice of physical inspection of the consignment at different sales points can be avoided and efficiency of marketing considerably improved when scientific grading of spices is adopted as an integral part of the marketing strategy.

(5) When the transactions are on the basis of well-known grades, the collection and dissemination of market prices become more accurate and meaningful. Thus, it would not be unreasonable to state that grading and standardization constitute the single most powerful measure that brings about an overall improvement in not only the marketing system of spices and condiments but also, in the long run, the quality of spice production in the country by creating quality consciousness among the growers as well as the consumers.

4.5 Grading of cardamoms

Dried cardamoms are cleaned by rubbing them gently over a coarse surface of wire mesh or bamboo trays in order to remove the stalks and all dried remains of floral parts. This is best done when the material is still hot. The cleaned or sorted cardamoms are then graded into longs, mediums and shorts.

4.6 Grading of cassia and cinnamon

Cassia and cinnamon barks are also sorted out and graded into quills, quillings, featherings and chips, based on their length, unit weight, colour, taste, texture, thickness, etc.

4.7 Grading of ginger

Dried, unbleached ginger rhizomes are gently rubbed by hand in order to remove the last bits of the skin or any adhering extraneous matter. They are then sorted into suitable grades prescribed under the various national standards such as those of the U.S. Department of Agriculture, the Food and Drug Administration, ASTA, National Standards Institutions, Agmark, etc., which vary somewhat from country to country.

4.8 Grading of onions

In the United States, most onions are graded in central packing sheds and warehouses, which are usually located along railroad sidings, where the bagged onions are run over power-operated mechanical graders that blow and screen out any dust and loose scales and grade the onions into different sizes. As the bulbs move along the grading table, undesirable ones are removed. Usually the several size grades are packed separately to make a more uniform and attractive product. Portable onion graders, which allow cleaning, grading and sacking in the field, are also used in some areas.

4.9 Grading of turmeric

The adhering scales and root bases or hairy roots are removed from cured and dried turmeric rhizomes (bulbs and fingers) by rubbing with the help of a coarse cloth or burlap, followed by winnowing. The cleaned product is then graded into fingers, bulbs, brokens, etc.

4.10 Grading of vanilla beans/cuts

Vanilla beans, after curing, are graded according to length and appearance. However, the system of grading of vanilla beans does not appear to be consistent. According to one system, there are four grades:

(1) Top class beans are cut up to 20cm in length, very dark, oily in appearance, show no defects, and have a good, powerful odour.

(2) Second grade. The lower grades are short, thinner, and lighter in colour and the odour is not so pronounced.

(3) Splits. When the beans are open at the end during the curing process, they are graded as "splits". Very thin pods are often combined with these.

(4) Cuts. If the beans have developed mould, then the mouldy portion is cut away and the rest is sold as cuts.

4.11 Grading of other spice

Various types/grades of several spices have been prescribed in International Standards formulated by ISO.

4.12 ASTA Cleanliness specifications for the unprocessed spices, seeds and herbs

The U.S. F.D.A. have reached a 'Self-Regulation' understanding with the American Spice Importers' so as to shift most of the work of 'spice sampling' and analysis from the FDA authorities over to the American Spice Industry members themselves. In exchange for this privilege given to the Industry the spice importers guarantee that spice shipments found by macroscopic analysis to be adulterated or contaminated should be returned to the exporting country or should be got properly cleaned or reconditioned before being put into consumer channels. The ASTA specifications contained in Table 3 established limits only for the extraneous matter which is removable by further cleaning/processing under good manufacturing practices to place the product in a condition fit for human consumption. However, these specifications do not define the total requirements of Food, Drugs and Cosmetic Act of the U.S.A.

For further details of the implementation of these ASTA specifications, reconditioning of spices, reconditioned items, sampling and techniques of physical analysis of spices, refer the original ASTA publication (1982).

5.0 Packing of spices and condiments

Spices and spice products are hygroscopic in nature, and being highly sensitive to moisture, their absorption of moisture may result in caking, discolouration, hydrolytic rancidity, mould growth and insect attack. Further more, they contain volatile aromatic principles, and the loss of these principles and the absorption of foreign odours as a result of inefficient packaging, may pose serious problems, especially in ground spices. In addition, heat and light accelerate deterioration, especially with oxygen-sensitive products.

Table 3. Cleanliness specifications of Spices

For purposes of these specifications, extraneous matter is defined as everything foreign to the product itself and includes, but is not restricted to; stones, dirt, wire, string, stems, sticks, non-toxic foreign seeds, excreta, manure and animal contamination.

The limits of the various contaminations permitted under these specifications are shown here.

CLEANLINESS	Whole insects dead	Excreta-rodent	Excreta others	Mold	Insect-defiled	Extraneous matter
Name of Spice, Seed or Herb	By Count	By Count	By Mg/Lb	% By Wt.	% By Wt.	% By Wt.
Allspice	2	2	5.0	2.00	1.00	0.50
Anise	4	4	5.0	1.00	1.00	1.00
Sweet basil	2	2	2.0	1.00	1.00	0.50
Caraway	4	2	10.0	1.00	1.00	0.50
Cardamom	4	2	1.0	1.00	1.00	0.50
Cassia	2	2	1.0	5.00	2.50	0.50
Cinnamon	2	4	2.0	1.00	1.00	0.50
Celery seed	4	2	3.0	1.00	1.00	0.50
Cloves	4	2	8.0	5.00	2.50	0.50
Chillies	4	2	3.0	1.00	1.00	1.00*
Coriander	4	4	10.0	1.00	1.00	0.50
Cumin seed	4	2	5.0	1.00	1.00	0.50
Dill seed	4	4	10.0	1.00	1.00	0.50
Fennel seed	** S.F.	** S.F.	** S.F.	1.00	1.00	0.50
Ginger	4	2	3.0	5.00	2.50	1.00
Ginger (split)	4	2	10.0	10.00	5.00	0.50
Laurel leaves	2	2	10.0	1.00	1.00	1.00
Mace	4	2	1.0	2.00	1.00	0.50
Marjoram	3	4	10.0	1.00	1.00	1.00
Nutmeg (broken)	4	2	1.0	*** S.F.	*** S.F.	*** S.F.
Nutmeg (whole)	4	0	0.0	10.00	5.0	0.00
Oregano	3	2	10.0	1.00	1.00	1.00
Black pepper	2	2	5.0	1.00	1.00	1.00
White pepper	2	2	1.0	1.00	1.00	0.50
Poppy seed	2	2	4.0	1.00	1.00	0.50
Rosemary leaves	2	2	4.0	1.00	1.00	0.50
Sage	2	2	4.0	1.00	1.00	0.50
Savory	2	4	10.0	1.00	1.00	0.50
Sesame seed	4	4	10.0	1.00	1.00	0.50
Sesame seed hulled	4	2	1.0	1.00	1.00	0.50
Tarragon	2	2	1.0	1.00	1.00	0.50
Thyme	4	2	5.0	1.00	1.00	0.50
Turmeric	3	2	5.0	3.00	2.50	0.50

* Clove stems - A 5% allowance by weight for unattached clove stems over and above the tolerance limit for other extraneous matter is permitted.

** Fennel seed: In the case of fennel seed, if more than 20% of the subsamples contains any rodent or other excreta or whole insects, the lot must be reconditioned.

*** Not more than 5% by weight insect defiled and mold combined.

With reference to packaging, spices may be classified into four categories (Pruthi 1985) as follows:

5.1 Classification of spices with reference to packaging

(A) Spices that need protection against light
Spices containing natural pigments, such as green cardamoms, capsicum, paprika and chillies, need to be protected from light. The colour of capsicums is mostly due to carotenoids, which are susceptible to oxidative deterioration in the presence of light. Spices containing chlorophyll, such as green cardamoms, also fade during storage if not protected against light and air. Similarly, turmeric which contains curcumin pignnent, also fades, although less rapidly than the spices containing carotenoids or chlorophyll. Saffron also is photo-sensitive. Mace also fades in light and sunlight in particular (Pruthi 1985).

(B) Spices that need special protection from loss or gain of flavour
The loss of flavour depends on the amount and the degree of volatility of the essential oil of the spice. For example, onion and garlic powders contain highly volatile sulphur compounds and therefore, need rigorous protection (Pruthi 1980).

(C) Spices that need protection against ingress of moisture and Oxygen
Almost all spices are generally marketed in dry condition, and most of them are hygroscopic in nature. Therefore, they need protection against the ingress of moisture. Besides, the essential oil components naturally present in most of the spices, are prone to oxidation by atmospheric oxygen; particularly at high storage temperature, resulting in the development of off-flavours. The ingress of moisture also encourages mould attack and insect infestation in spices. However, most of the whole spices are protected by natural antioxidants present therein, and therefore need less rigorous protection than do the ground spices.

(D) Ground spices
Ground spices, because of the greater surface area exposed, lose flavour faster as a result of the loss of volatile oil, and they absorb or lose moisture faster, depending on the atmospheric humidity surrounding them and the storage temperature. Thus, they deteriorate much more rapidly than do whole spices. They are more susceptible to mould and insect attack. Therefore, ground spices need special attention in packaging to protect them against such rapid deterioration.

5.2 Determination of packaging requirements of spices

For the systematic determination of packaging requirements and storage characteristics of foods in general, and of dehydrated or dried products like spices in particular, the measurement of equilibrium relative humidity (ERH) is of considerable importance. Hygroscopicity is one of the most important characteristics of dehydrated or dried foods, it is influenced mainly by the moisture content of the product itself and the humidity in the atmosphere over it. The relationship of hygroscopicity and hygroemissivity to the moisture equilibrium curve or sorption isotherm, shows the equilibrium relationship between the moisture content of the spice and the atmosphere immediately over it. Products having ERH less than 50% are usually considered hygroscopic, whereas those with ERH above 50% are hygroemissive.

The author and his associates studied the chemical composition and packaging requirements of a number of spices, viz. aniseed, green cardamom, large cardamom (brown), coriander, ginger, mustard powder (imported and Indian), onion powder, onion salt, mace, pepper (black and white), red chillies, and turmeric (whole and powder). Data based on Wink's weight equilibrium method and pertaining to sorption isotherms and equilibrium relative humidity (ERH), equilibrium moisture content (EMC), and the moisture content at which mould attack was visible, are presented in Table 4. These studies show that, of the several spices and condiments studied, garlic powder, garlic salt, onion powder, mustard powder, cinnamon, and chilli powder were comparatively much more hygroscopic than the other spices. And their ERH ranged from 5 to 10% only (Pruthi 1980; Pruthi, Venkataram & Jayaraman 1962).

5.3 Selection of packaging materials

Packaging of foods is usually utilitarian and protective. The primary purpose of a food packer is to preserve the flavour and keep the product in good condition until it reaches the consumer. The journey from prime producer to ultimate consumer is often long, sometimes half way around the world. The waiting at the distribution way stations vary from days to months and sometimes is of unpredictable duration. Yet the product must reach the consumer in usable condition, with its fresh flavour and its attractive appearance unimpaired. Throughout the journey the package must protect the contents from thermal changes, humidity variations, hazards of rough handling, rodents and insect infection. An ideal package meeting all these requirements is extremely rare.

5.3.1 Objective assessment of packaging materials

A large number of factors must be considered in detail when one is choosing a suitable packaging material for flavour foodstuffs. These factors may be grouped into two categories; basic factors and consumer acceptance factors (Pruthi 1980).

Basic factors : (1) Price to packager (2) sanitary qualities (protection of product from contamination) (3) resistance to impact injury (4) effectiveness of interior surface (5) absence of handling problems (6) space and other storage requirements in the filling plant and in distribution, including weight of package and (7) special features relating to performance of packager.

Consumer acceptance factors include : (1) size (2) ease of opening (3) reseal features (4) pouring qualities (5) space saving on consumer's premises (6) protection from light (7) transparency (8) tamper proof construction (9) physical characteristics of outside surface, including appearance (10) ease of disposal and (11) special features relating to performance for consumer.

To summarize, the package should fulfill two important functions; it must sell its contents as well as protect them. The sale function includes attractive advertising potential, protection from mechanical damage and reasonable cost. The protective function includes compatibility with the product and protection against climatic conditons, microorganisms, insects and filth, and flavour gain or loss. Finally, the package should fit in the production line to facilitate automation (Pruthi 1985).

Table 4. Initial moisture, equilibrium relative humidity, critical moisture and critical relative humidity at which mold attacks whole and ground spice at room temperature (25° - 28°C)

Spice	Initial moisture (%)	Equilibrium relative humidity (%)	Mold growth at moisture level (%)	Mold growth at relative humidity (%)
Cardamom large (Amomum)	7.78	45	11.46-22.19	73 and above
Cardamom (green)	10.46	40	16.90-22.78	73 and above
Black pepper (whole)	8.19	28	17.74-23.34	73 and above
Black pepper (powder)	6.48	29	13.92-16.02	73 and above
White pepper (whole)	5.09	20	14.47-17.10	81 and above
White pepper (powder)	6.64	18	15.11-18.79	81 and above
Red chilli (whole)	4.63	10	16.50-24.67	81 and above
Red chilli (powder)	7.48	8	21.28-28.39	81 and above
Ginger (powder)	7.50	28	13.80-20.00	73 and above
Ginger powder (sweetened)	6.50	11	11.00 and above	73 and above
Curry powder	6.71	28	16.43-22.41	81 and above
Mace (whole)	4.33	43	9.74-13.34	81 and above
Fennel seed (whole)	8.16	50	24.33	91 and above
Aniseed (whole)	8.00	62	24.11	91 and above
Celery seed (whole)	8.96	53	25.09	91 and above
Fenugreek seed (whole)	7.73	40	23.59	81 and above
Coriander seed (whole)	6.68	43	13.57-19.19	81 and above
Coriander seed (powder)	7.18	22	21.81	91 and above
Cinnamon (whole)	3.24	4	16.67	91 and above
Clove (powder)	6.42	30	22.19	91 and above
Garlic (powder)	6.00	13	No mold	No mold
Garlic salt	2.46	5	No mold	No mold
Mustard flour	6.48	6	15.90-23.30	81 and above
Turmeric powder	8.0	22	12.43	91 and above
Onion powder	1.0	5	62.46	96 and above

5.3.2 Types of packaging materials

The various materials suitable for packaging of foods include paper products, polyethylene flexible films, aluminium foils, glass, tin, hessian and timber. The selection of packaging material intrinsically will depend on the nature of the product and other considerations. Only the important ones are briefly discussed below:

(1) Paper and Cardboard Cartons are the least expensive unit packages for whole spices. They have good advertising potential and can be folded into any shape. Wax coating on the outside improves attractiveness as well as resistance to water (wet strength). Polyethylene coating inside gives extra protection as well as sealability. Paper and cardboard cartons are, however, unsuitable for ground spices, owing to their high permeability to flavour components and gases. This disadvantage can be overcome by inner pouch of suitable polyethylene (Pruthi 1980).

(2) Aluminium foil. Foil offers excellent potential for packaging ground spices. Aluminium is not transparent and is ideal for spices that need protection from light. Its resistance to gas transmission is essential to protect the delicate flavour of many spices. It is subject to puncture, but this can be overcome by laminating the outside with paper.

Heat sealability can be achieved by coating the inside with a heat sealable film such as polyehtylene.

(3) Combination of films. Since a single film does not fulfill all the functional requirements, a combination of films can be used to obtain the desired effect. This can be done by lamination, coating or co-extrusion. The properties of various films in increasing order of their cost as prevalent in the United States are summarised in Table 5.

Table 5. Properties of packaging films

Packaging materials	Barrier properties (a)	Strength (b)	Functional properties (c)
Polyethylene	Poor	Poor	Good
Polypropylane	Poor	Good	Good
Aluminium oil	Superior	Superior	Good (d)
Polystyrene	Poor	Superior	Good (e)
Polyvinyl chloride	Poor	Poor	Good
Rubber hydrochloride	Good	Good	Good
Polyvinylidine chloride	Superior	Superior	Good
Nylon	Good	Superior	Good
Polyester	Superior	Superior	Good (f)

(a) Barrier properties: resistance to water vapour, gases and essential oil
(b) Strength: rigidity and durability
(c) Functional properties: clarity, machinability, heat sealability and printability
(d) Not heat-sealable and not transparent
(e) Not heat-sealable.
(f) Coextruded multilayer films.

(4) Coextruded Multilayer Films have totally revolutionised flexible packaging in the advanced countries. In the U.S.A. alone, for example, their usage has grown by almost 800% in the last five years and what is more, this rate of growth is expected to be maintained right through this decade.

Not only have coextrusions proved to be functionally superior to other conventional laminates and rigid packaging systems like metal cans, glass jars, plastic bottles and cartons but they have invariably been much more cost-effective. In fact, the packager's dream - a perfectly safe flexible retort food pouch - has been realised only after the advent of coextrusions (Anon 1989).

Advantages of co-extruded films

(i) They do not use adhesives and thus totally eliminate problems associated with adhesive leaching, residual solvents or moisture, odours and problems associated with handling flammable and volatile solvents in the plant. Consequently, rates of output are also much higher since they are not constrained by drying rates of solvents or moisture.

(ii) There is no limit to the number of plies that one can economically use as all these are combined in just one operation at no additional cost. In lamination, every additional ply means an additional operation and therefore, increased cost and material wastage.

(iii) Optimisation of material usage is easy and ply thickness as low as 5 microns can be produced. Other lamination processes require much higher minimum ply thickness in order to be able to handle them.

(iv) A number of high-barrier but unstable resins like EVOH were hitherto unavailable for use, in coextrusion, they are simply sandwiched between stable layers of other polymers. Consequently, coextruded structures have been produced that are on par with even aluminium foil laminates but cost much less.

(v) The range of possibilities in terms of polymers, their grades, thickness, number of plies and combination of properties is virtually infinite. Coextrusions are the ultimate in tailor-made multilayer structures even for the most exacting package requirements.

Coextruded multilayer films are generally used as pouches, bags, strips, over wraps, liners, lables, lidding material, tapes, stretch wraps for bulk loads or simply as base film for conversion and lamination to other substrates like paper and boards, foils, fabrics or oriented films (Anon 1989).

(5) Tin and wooden containers. Some of the costly spices having a delicate, thermolabile aroma, such as saffron, are packed in butter paper and further packed in suitable tin containers. Cured vanilla, cardamom seed, etc. are packed on wooden boxes suitably lined and made as airtight as possible.

6.0 Present status of packaging

The various types of containers used at present in different parts of India and other spice-growing countries for different spices, their sizes, capacity, tare

Table 6. Suggested bulk and retail packaging for important spices and spice products

Spice/spice product	Opt. moisture content (%)	Bulk packaging	Retail packaging
Black pepper (whole)	10-11	Double burlap bags with sealed polyethylene liners 0.0003 inch or more thick	1. HDPE 200 gauge with printed cardboard boxes, or 2. laminated aluminium foil 3. MST film 4. Coextruded
Black pepper powder	9-10	-	Laminated heat-sealable (PE coated) aluminium foil, moisture proof cellulose film (MST) coextruded films shelf-life 6 months
Cardamom green	10	Wooden chest lined with tinfoil or P.E. 300 gauge or craft paper coated with bitumin weight 1 cwt each. Shelf-life 2-3 months	300 gauge black polyethylene lined packages stored in wooden chests lined with tin foil or craft paper shelf-life 4-5 months.
Chillies/Red peppers	10	(a) Wooden crate dunnage with a layer of matting (b) Conditioned 10% moisture, compressed at 2.5 kg/cm^2 by using baling process.	Packing with Mylar-Saran PE plastic laminate and aluminium pouches, under N_2 - Can keep for 1 year.
Chilli powder	10	-	Packaging in AFC pouches, black polyethylene pouches.
Turmeric powder	10	-	-do-
Garlic Powder	5-6	Packing under N_2 in sealed tin-containers and storage at low temperature	AFC or Aluminium foil combination of small friction of top tins with minimum head space and storage at low temperature

Onion powder	5	-do-	-do-
Curry powder	8-9	Packing in hermetically sealed tin containers or sealed friction top tins. Shelf-life 4-5 months	Packing in AFC or small hermetically sealed containers. Shelf-life 4-5 months at room temp.
Saffron powder	8.00	Air-tight tins lined with waxed or butter paper	AFC or poly bags or waxed paper bags kept in cardboard boxes.
Saffron(whole)	14.00	-do-	-do-
Vanilla (beans)	30.00	-do-	-do-
Vanilla (powder)	20.00	-do-	-do-
Spices (general)	10.00	Nylon/LDPE,PP/ EVOH/PP	-

weight, cost, etc., are described in a series of Marketing Reports published by the Directorate of Marketing and Inspection.

However, the available published information on suggested packaging for bulk as well as retail packaging has been summed up in table 6 which also contains the recommended optimum moisture content from the viewpoint of mould infestation, etc. (Pruthi 1980,1987, 1991).

6.1 Future R & D scope

As would be seen from tables, there is considerable scope for further R & D work, for innovations in packaging of whole and ground spices and their products.

Selected References

Abraham P 1965 The cardamom in India. Farmers Bull. 37. ICAR, New Delhi.

American Spice Trade Association, New Jersey, USA 1982 Cleanliness specifications for unprocessed spices, seeds and herbs: foreign and domestically produced. pp 1-10 (Revised March 1982).

Anon. (Dte. of Marketing and Inspection Govt. of India) 1982 A.P.G.M. Act, 1937 with rules amended up to 31.12.79. Marketing Series. No. 192 Compendium. Vol. 1, pp. 1-431. 5th Edition.

Anon. 1987 IDEM Act with rules amended up to 31.03.1985 1st Ed. Compendium Vol. II. Marketing Series No. 193. pp 1-192.

Anon 1989 Coextruded films - A package deal. Pamphlet, New Delhi.

Breag G R, Crowd L P G, Nahney J & Robinson F V 1972. Artificial drying of pimento. Proc. Int. Conf. Spices. Trop. Prod. Inst, London, 172, p. 149.

Desikachar H S R, Srinivasan M & Subrahmanyan V 1959 Processing of turmeric. Res. India. 4, 172.

Havinghorst C R 1955 Food Engg. 27(5), 63.

Kannan K & Pillai G G 1966 Vanilla. Indian Farming, 16(2), 4.

Katyal S L 1967 Saffron. Indian Hort. 11:(3) 5.

Larcher J 1967 Agron Trop. (Paris), 22, 1094.

Laul M S, Bhalerao S D, Rane V R & Amla B L (1970) Sun-drying of chillies. Indian Food Packer 24(2), 22.

Lease J G and Lease E J 1956 Effect of fat-soluble antioxidants on the stability of red colour of peppers. Food Technology 10, 403.

Kuppuswamy S 1974 Proc. Symp. 'Dev. Prospects for Spices Industries in India' p. 29.

Mariwala J V 1974 Processing of pepper. Proc. Symp. : Dev. Prospects for Spice Industries, 1974, 17.

Nair P C S and Mathew L 1969 Vanilla. Indian Spices 6(4) p.2.

Natarajan C P, Padmabai R, Krishnamurthy N, Raghavan B, Shankaracharya N B, Kuppuswamy S, Govindarajan V S and Lewis Y S 1972. Chemical composition of ginger varieties and dehydration studies on ginger. J. Food Sci. & Technol. 9: 220.

Pruthi J S 1980a Spices & Condiments - Chemistry, Microbiology and Technology. Academic Press Inc., New York (USA).

Pruthi J S 1980b Recent trends in the packaging of spices and spice products'. Seminar on 'Innovations in Packaging of Processed Foods'. SISI, New Delhi, pp. 1-7.

Pruthi J S (ed) 1987 Spice Industries - Present scenario, problems and prospects. Tech. Compendium.

Pruthi J S (ed) 1987 Bibliography on Spices (1972-1986) Assoc. Fd. Sc. & Tech. India, Delhi.

Pruthi J S 1991a Major Spices of India - Crop Management and Post-Harvest Technology. India Council of Agrl. Research, New Delhi.

Pruthi J S 1991b Minor Spices and condiments - Crop Management and Post-Harvest Technology. Indian Council of Agrl. Research, New Delhi.

Pruthi J S 1991c Spices and Condiments 7th Edn. 1991. National Book Trust, New Delhi.

Pruthi J S *et al.* 1959 Garlic powder technology. J. Food. Sci, 8: 429-464 (a series of 10 papers).

Pruthi J S & Lal G 1960 Studies on ERH on Onion Powder. Curr Sci, 29, 19.

Pruthi J S, Venkataraman S G and Jayaraman A 1962 Studies on the chemical composition and sorption isotherms of spices and spice products. Proc. Symp. 'Spices -- Role in National Economy'. p.10.

Pruthi J S, Varkey G & Bhat A V 1987 Post-harvest technology of cinnamon Indian. Arecanut Spices and Cocoa 1:87.

Purseglove J W *et al* 1981 Spices Vol. I & II, Longman, London.

Raina B I, Teotia M S & Pruthi J S 1978 Technological assessment of ginger grown in H P. Proc. First Ann. Conven. Fd. Sci. Technol. p.47.

Ramanathan P K & Rao P N S 1974 Equipment needs of the spice industry. Proc. Smp.: "Spice Industries - Dev. Prospects". p. 82.

Richardson K C 1966 Effect of dehydration temperature on quality of ginger. Food Technol. 18. 95.

Rodriguez D W 1971 Commodity Bull. No: 4, Agric. Planning Unit, Mini. of Agric. and Fisheries, Jamaica

Shankaracharya N B & Natarajan C P 1973 Indian Food Packer. 26(6) p. 14.

Sharpnell G S 1967 Technological developments of ginger industry in Australia. Food Technol. 19, 604.

Srinivas S R, Pruthi J S and Siddappa G S 1962. Determination of optimal harvest time for ginger for processing. Proc. 'Symp. spices - Role in National Economy'. p.4 ICAR Newsletter.

Theodose R 1972 Traditional methods of vanilla preparation, improvement of these techniques at the Antalaha Station (Madagascar). Proc. Int. Conf. Spices. Trop Prod. Inst. London 1972, 71.

Van Bharicum L O & Martin J A 1951 Food Technol. 5, 337

Vijayan P K 1974 Solar energy for cardamom curing. Proc. Symp. Spices, p. 37