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Processing and quality of black pepper – a review

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Abstract

Processing of pepper involves different unit operations such as threshing, blanching, drying, cleaning, grading and packaging. These operations are important to ensure clean and quality products. Various mechanical gadgets available for threshing, cleaning, drying etc. are reviewed. A wide range of threshers with a capacity ranging from 50 to 1200 kg h^{-1} are available. However, some of the threshers and cleaners need improvisation for commercial acceptability. Cleanliness and quality standards like Agmark, standards prescribed by American Spice Trade Association (ASTA) and European Spice Association (ESA) are reviewed. Different methods for preparation of value added products like dehydrated green pepper, canned green pepper, white pepper, ground pepper, pepper oil etc. have also been covered in this review.

Key words: black pepper, cleaning, drying, grading, post-harvest processing, threshing, storage

Introduction

Black pepper is the whole dried fruit of the vine *Piper nigrum* L. It is a native of the Western Ghats in India where more than hundred known cultivated types are reported (Ravindran *et al.* 2000). It is a perennial glabrous woody climber of 5 m or more in height with a bushy columnar appearance. The spikes are borne on the plagiotropic branches opposite to the leaves and are 3 to 15 cm long. The fruits or berries are 4 to 7 mm in diameter and have a pulpy pericarp and a hard endocarp (Purseglove *et al.* 1981).

Black pepper is widely used as a condiment due to its characteristic aroma, pungency and biting taste. The two primary products of *P. nigrum* that are internationally traded are black pepper and white pepper. Black pepper is used directly as a spice and also for the preparation of its derivatives namely essential oil and oleoresin. Indian pepper, commonly known as "Malabar pepper" is considered to be the best in the world for its excellent aroma, flavour and pungency.

Black pepper accounts for 35 per cent of the total world trade in spices. India is the largest producer, consumer and exporter of black pepper. India funnels about 25 to 40 per cent to the total world production and thus occupies a unique position in the international marketing of pepper (Pruthi 1980). The annual production of pepper is around 60,000 – 85,000 tonnes. The pepper producing areas in India are Kerala, Karnataka, Tamil Nadu and North Eastern States. Some of the popular cultivars and varieties of black

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pepper in India are Panniyur, Karimunda, Kottanadan, Balankotta, Neelamundi, Narayakodi, Arakulamunda, Kalluvally, Aimpiriyan, etc. (Ravindran *et al.* 2000).

Harvesting

The maturation period of pepper varies from 5 to 6 months in Indonesia and 7 to 8 months in India. In India, the crop is harvested during December - January in plains and January – April in the high ranges of Western Ghats. It is important to harvest pepper at the proper maturity in order to achieve a dried product of good colour and appearance. The spikes are nipped off by hand and collected in bags when one or two berries in the spike turn red or yellow. As harvesting is done manually, multiple harvesting is not preferred to reduce the cost. Normally, single pole bamboo ladder is used as a support for harvesting. If the berries are allowed to over ripe, there is heavy loss due to berry drop and damage by birds.

Recent advances in product diversification have necessitated harvesting of the berries at different stages of maturity to meet the specific needs of the end product. The level of maturity required at harvest for processing into different pepper products is given in Table 1.

The changes in chemical composition of pepper from the earliest maturity to ripe stage have been studied by Sumathykutty *et al.* (1980). The volatile oil and piperine concentration were found to increase up to just before full maturity and thereafter decrease during ripening stage. Starch content showed an increasing trend during the entire maturity period.

Table 1. Optimum maturity at harvest for different pepper products (Natarajan 1981)

Product	Stages of maturity
White pepper	Fully ripe
Black pepper	Fully mature and near ripe
Canned pepper	4 – 5 months
Dehydrated green pepper	10 – 15 days before full maturity
Oleoresin & essential oil	15 – 20 days before maturity
Pepper powder	Fully mature with maximum starch

Threshing

Trampling with legs is the traditional method followed for despiking. This operation is crude, tedious and unhygienic. Chances of extraneous matter, soil particles and filth contaminating the produce are also high. The harvested spikes are sometimes piled up for a day or two before threshing to facilitate easy separation of the berries from spike (Risfaheri & Nurdjannah 2000). At few places, mechanical threshers are put into use by institutions, farmers and corporates.

A pepper thresher developed indigenously at St. Joseph's Estate, Gudalur, Tamil Nadu (Fig. 1a) was very efficient and caused only minor damage to pepper corns during threshing (Ravikumar *et al.* 1998). Kerala Agricultural University (KAU), Trichur has developed a thresher of 50 kg h^{-1} capacity. Tamil Nadu Agricultural University (TNAU), Coimbatore developed a pepper thresher of 200 kg h^{-1} capacity with 84.5 per cent efficiency (Madasamy & Gothandapani 1995a). The efficiency of the thresher has been enhanced recently to 99.6 per cent (Fig. 1b).

A thresher fabricated in Malaysia had an average threshing efficiency of 92.25 per cent, which however reached 99.8 per cent by increasing the time of threshing (wan Ismail *et al.* 1984). Rishaferi & Hidayat (1996b) developed two types of threshers in Indonesia, one using manpower and the other with electrical power. The mechanism of the equipment was based on impact and friction that occur in the area between threshing cylinder and concave surface.

A commercial firm at Bangalore, Karnataka is marketing a pepper thresher of 1200 kg h^{-1} capacity under the brand name "Mohta Thresher". Units of this type have been installed at many places and are working well. Another model called "Cafex Thresher" is being marketed by a firm at Chickmaglur, Karnataka. Two other models of pepper threshers are being marketed by an industrial establishment based at Coimbatore under the brand name "Vivega" (Fig. 1c). These threshers have a capacity of 50 kg h^{-1} and 200 kg h^{-1}, respectively. The comparative performance of various threshers is presented in Table 2.

Since quality is the watchword in export, mechanized threshing is a means to improve or maintain the quality. Introduction of suitable threshers reduces the chances of contamination and ensures clean and hygienic produce.

Drying

Drying is the most important processing step for all spices. Pepper has a moisture content of 60 to 70 per cent at harvest, which should be brought to safer levels by adequate drying. The green colour of matured pepper is due to chlorophyll pigment. During drying, enzymatic browning sets in and the phenolic compounds are oxidised by atmospheric oxygen under the catalytic influence of the enzyme phenolase and eventually the berries turn black (Mathew 1994). The dry recovery varies from 29 to 43 per cent depending on the variety.

The conventional method followed for drying black pepper is sun drying. The despiked berries are dried in the sun for 4 to 7 days to bring the moisture content below 10 per cent. In sun drying, periodic turning of the lot is needed to achieve uniform drying. Otherwise it may lead to heavy mould contamination resulting in a poor product with grayish and unattractive appearance (Govindarajan 1977). In order to achieve a quality product, pepper has to be dried on clean surface, otherwise, dust and other extraneous matter get accumulated along with pepper. Polythene sheets, cement floors and fenugreek paste coated bamboo mats are recommended for this.

Drying of black pepper was carried out on different surfaces by Krishnamoorthy & Zachariah (1992) and Rajagopalan *et al.* (1999). LDPE, HDPE, cement floor and bamboo mats were used as drying surface materials. It was observed that there was no significant difference in the drying time and colour of pepper on all drying materials. However, HDPE sheet offers easy handling while spreading and heaping and yielded a better product in terms of cleanliness, moisture content and quality.

An innovative technique involving blanching of green berries in boiling water for one minute has been standardized by Central Food Technological Research Institute (CFTRI), Mysore, Karnataka. In this method, berries are cleaned and collected in perforated vessel or bamboo basket and dipped in boiling water for one minute (Pruthi 1993). The advantages of blanching treatment are accelerated drying, uniform dark glossy black colour, reduction in dust and foreign matter and microbial contamination. Enhanced oxidation of phenols by phenolase enzyme during blanching imparts a dark glossy colour (Mathew 1994). Risfaheri & Hidayat (1993) suggested blanching of pepper berries in hot water at 80°C water for 1.5 to 5 minutes prior to sun drying. However, prolonged blanching in water can deactivate the enzymes responsible for browning reaction and causes discolouration of black pepper. Studies at Indian Institute of Spices Research (IISR), Calicut showed that blanching could reduce the microbial load by 75 to 90 per cent. According to Krishnamurthy *et al.* (1993), in Panniyur and Karimunda varieties, blanching could reduce the drying time up to 44 per cent without affecting the volatile oil, piperine and oleoresin content.

If weather conditions during harvest of pepper are favourable, solar dryers are highly efficient for drying black pepper. Solar cabinet dryer with aspirator has been developed at Central Institute of Agricultural Engineering(CIAE), Bhopal, Madhya

Table 2. Comparison of black pepper threshers developed by different agencies

Parameter	Model/ make of thresher									
	Gudalur thresher	KAU thresher	TNAU thresher (Improved model)	Malaysian thresher	Indonesian thresher		Vivega thresher		Mohta thresher	Cafex thresher
					Manual	Power	Manual	Power		
Capacity (kg h^{-1})	600	50	200	600	170 – 185	425 – 450	50	200	1200	600
Power source	2 hp motor	0.5 hp motor	1 hp motor	NK	Pedal operated	3 hp motor	Hand operated	3 hp motor	3 hp and 1 hp motor	3 hp motor
Threshing mechanism	Wooden cylinder with aluminium angles	Metal drum with rubber lining	Metal drum with rubber lined rasp bar	Metal drum lined with rubber blades	Metal drum	Metal drum	Metal drum with angles	Metal drum with angles	Metal drum	Metal drum
Max. efficiency (%)	99.5	98.0	99.6	99.8	94.13	92.21	91.5	96.0	Nearly 100	98.0
No. of passes	2 - 3	2 - 3	2	2	NK	NK	3	2	1 - 2	2
Damage (%)	< 0.3	< 0.5	Negligible	NK	3.78	6.13	4.0	> 4.0	Negligible	< 0.5

NK – Not known

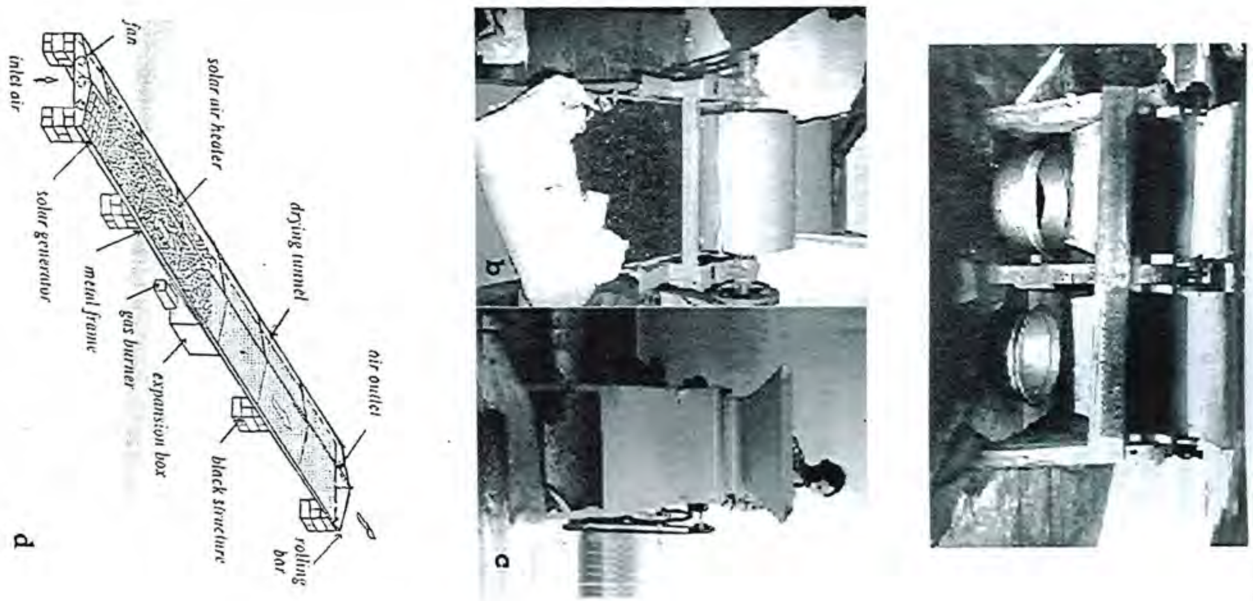

Fig. 1. Different types of balck pepper threshers. a. Gudalur thresher; b. TNAU thresher (improved model); c. 'Vivega' thresher (power operated); d. Solar tunnel dryer

Pradesh. The dryer could be used for spices like black pepper, cardamom, nutmeg etc. (Kachru & Gupta 1993). Prototypes of solar dryers developed at Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala, TNAU, KAU and Planters Energy

Fig. 2. CPCRI dryer

Network, Madurai, Tamil Nadu could be employed for drying black pepper. Solar tunnel dryer (Fig. 1d) developed at Mithradham Renewable Energy Centre, Sacred Heart College, Cochin, Kerala has been tested for drying a variety of agricultural produces including spices (Joy *et al.* 1999; Pittappillil 2000).

ASTRA dryer developed at Indian Institute of Science, Bangalore can be used for drying variety of products including black pepper. One such unit is installed at IISR Cardamom Research Centre, Appangala, Karnataka for drying cardamom. It is a batch tray dryer containing a cabinet for housing odd number of trays, an efficient stove at the bottom for burning the biomass fuel, ducts for conveying the flue gases through various locations and ports at the bottom to suck-in the drying air (Anonymous 1998).

An agricultural waste-fired copra dryer developed by CPCRI (Fig. 2) was evaluated at IISR for drying black pepper. At a spreading density of 6 kg m^{-2}, drying was achieved in 9 h at 60 to 65°C. The resultant produce had dark black colour and a glossy appearance.

A tray type dryer consisting of a heater, drying chamber with trays and plenum chamber was developed at Research Institute for Spices and Medicinal Crops (RISMC), Bogor, Indonesia (Nurdjannah & Hidayat 1996). Under the plenum, it has iron pipes that act as a heat exchanger. Capacity of the dryer is 200 – 225 kg per batch.

Some of the progressive traders have installed cascade type dryers using kerosene oil or gas as fuel. The moisture in partially sun-dried pepper is brought down from 25 to 10 per cent in two stages in a counter-current hot air flow system. The technical reason for two stage drying is that in the first stage of drying, surface of pepper berries dries fast, but moisture within the core requires some time to diffuse out to the surface (Pruthi 1993).

The quality of pepper is mainly decided by the drying method and the extent of drying. The initial appearance, the level of microorganisms, mould contamination and susceptibility to insect infestation are dependent upon the care taken during drying (Pursegolve *et al.* 1981). When drying is not adequate, mould appears on the product affecting its appearance, quality and value. The optimum moisture content for the safe storage of black pepper has been proved to be 8.20 per cent at 25 to 28°C (Kachru *et al.* 1990).

Hot air drying and solar drying require less space due to higher spreading density besides saving drying time. After drying, the dried product is rather free from dust and other contaminants. The higher temperature build-up during drying results in a glossy dark black coloured product that can fetch a better price (Patil 1989). Studies at IISR showed that when pepper is dried at 60 to 65°C, microbial load is completely eliminated.

Cleaning and grading

The threshed and dried pepper has extraneous matter like spent spikes, pinheads, stones, soil particles etc. mixed with it. Cleaning and grading are basic operations that enhance the value of the produce and help to realise higher returns. On a small scale, most of these impurities are removed by winnowing and hand picking. Some farmers have developed cleaners locally. They are very simple in construction and easy to operate. Such units consist of a fan/blower and a feeding assembly. The fan/

blower is placed at the rear end of the hopper. Cleaning is achieved by feeding the material through the hopper into a stream of air blowing in perpendicular direction. The heavier fractions (mature berries) fall nearby while the lighter fractions (dust, immature berries, pinheads and spent spikes) are blown away.

KAU developed a multiple sieve rotary type cleaner cum grader for farm level operation. The unit consists of three concentric cylindrical sieves welded at one end on a circular mild steel plate. Under optimum conditions, the cleaning and grading efficiency are found to be 65.00 and 99.63 per cent, respectively. However, this is not popular among farmers.

TNAU has evaluated a gravity based spiral separator for cleaning black pepper (Madasamy & Gothandapani 1995b; 1996). This unit is ideal for cleaning foreign materials like rodent excreta and spent spikes from dried pepper. Cleaning is based on the coefficient of friction and shape. Cleaning efficiency of the unit was found to be 98.60 per cent at 120 kg h^{-1} capacity.

Varadharaju & Sreenarayanan (1992) developed an inclined belt separator for cleaning black pepper. The principle of separation is based on roundness and surface texture. This unit could be employed for removing spent spikes and other vegetative matter from good pepper berries. A separation efficiency of 98 per cent at 50 kg h^{-1} capacity has been achieved.

CFTRI has developed a processing unit with a capacity of 100 kg h^{-1} for continuous pre-cleaning and grading. It consists of an aspirator, destoner, rotary washer, continuous fluidised dryer, air classifier and grader. The processed product is free of dust, extraneous matter and of exportable quality (Natarajan 1981).

At processors' level, before packing, dried pepper is mechanically cleaned to get rid of extraneous matter such as dirt, stalks, spent spikes, pinheads, stones etc. and also graded according to size or density of berries. Pneumatic separators equipped with magnetic gadgets are used to remove debris based on specific gravity. Magnetic separators remove metallic contamination such as iron filings. Vibratory conveyors with inclined decks in combination with air classification are used for de-stoning of black pepper (Pruthi 1992). In export houses, pepper is cleaned and graded with the help of a multiple sieve cum air classifier whereby dust, stalks, pinheads, immature berries and extra bold pepper are conveniently separated. These machines are highly efficient and are capable of handling large quantities.

Using sieves, cleaned pepper is sifted into different grades based on size. Well-defined grades have been established by Agmark - Directorate of Marketing and Inspection (DMI). These standards are being implemented rigorously under the Compulsory Agmark Grading Scheme for exports from India. The grades are as follows (Pruthi 1993):

- Malabar Garbled (MG Grades 1 and 2) Black Pepper
- Malabar Ungarbled (MUG Grades 1 and 2) Black Pepper
- Tellicherry Garbled Black Pepper Special Extra Bold (TGSEB)
- Tellicherry Garbled Extra Bold (TGEB) Tellicherry Garbled (TG)
- Pinheads (PH Grade special and Grade 1)
- Garbled Light Pepper (GL Special, GL Grades 1 and 2)
- Ungarbled Light Pepper (UGL Special, UGL Grades 1 and 2)
- Black Pepper (Non-specified)

Storage

Black pepper is hygroscopic in nature and absorption of moisture from air, notably during rainy season with high humidity may result in mould and insect infestation. Pepper needs protection against ingress of moisture, light, heat and loss of aroma or flavour during storage. Before storage, it should be dried to less than 10 per cent moisture and garbled. All moulds and insects should be removed from the pepper berries by cleaning, washing, drying and garbling prior to storage. Pepper should be stored in double burlap bags with polyethylene liners of 0.076 mm or more in thickness. Maintaining the moisture content at a low level during storage not only prevents further mould development but also inhibits propagation of microorganisms and insects.

Quality and its control

The alkaloid piperine is the major constituent responsible for the biting taste of pepper. Other pungent alkaloids are chavicine, piperidine and piperattine (Zachariah 1998). Piperine content in pepper ranges from 4 to 10 per cent but this represents crude piperine, the content of true piperine being lower (Pruthi 1993). Chavicine is said to be the most biting ingredient of pepper. However, starch is the predominant constituent of pepper, ranging from 35 to 40 per cent in black pepper and 53 to 58 per cent in white pepper (Govindarajan 1977). The physical and thermo-physical properties of black pepper have been reported by Mulyono *et al.* (1995). The average composition of dried pepper is presented in Table 3.

The quality of black pepper is largely determined by berry size, colour, light berry content, damaged berries, moisture content, microbial load, presence of foreign matter like animal excreta, insect infestation etc. These factors are essentially determined by the harvesting, processing and handling practices at the growers' level and grading

Table 3. Average composition of black pepper (Pruthi 1993)

Constituent	Composition (%)
Moisture	8.7 – 14
Starch	28.0 – 49
Crude fibre	8.7 – 18.0
Piperine	1.7 – 7.4
Total ash	3.6 – 5.7
Non volatile ether extract (Oleoresin)	3.9 – 11.5

and storage practices adopted at the exporters' level. Another quality aspect gaining importance is the microbial contamination level, which should not exceed acceptable limits (Purseglove *et al.* 1981). It is imperative on the part of the producing country to bring out the microbiological specifications in future for wider acceptability.

In international market, quality specifications for trade are laid out by the importing as well as producing countries. The parameters assessed are extraneous matter, light berries, pinheads, bulk density, insects, excreta and microbiological aspects like presence of *Salmonella*, *E. coli*, aflatoxins etc. American Spice Trade Association (ASTA) or European Spice Association (ESA) or International Pepper Community (IPC) or International Organization for Standardization (ISO) specifications are the commonly adopted standards in international trade. The Agmark, ASTA and ESA specifications for cleanliness and quality are given in Tables 4 and 5. Among them, the cleanliness specifications for spices prescribed by ASTA, which are also approved by the United States Food and Drug Administration (USFDA) are widely accepted among the consumers. Producing countries have made all efforts to supply black and white pepper as per ASTA specifications. For the export of black and white pepper to the developed countries, the exporters have to meet the regulatory standards with regard to micro-cleanliness specifications such as microbial contamination, aflatoxin, trace metal contamination, pesticide residues etc. ESA limits on microbial and heavy metal contamination are given in Tables 6 and 7.

Pepper has a microbial load ranging from 3×10^3 to 28×10^6, and a mould count from 3×10^3 to greater than 3×10^5 per gram, but coliforms were fewer than 100 per gram (Warmbrod & Fry 1966). *Clostridium perfringens*, *E. coli*, *Aspergillus flavous* and *Salmonella* have been reported (Krishnaswamy *et al.* 1971). Cold sterilization by irradiation, vacuum fumigation with and

Table 4. Agmark specifications for Tellicherry garbled black pepper (Pruthi 1993)

Grade	Size (diameter of holes in mm of the sieve on which retained)	Extraneous matter not exceeding (% by weight)	Light berries not exceeding (% by weight)	Moisture content not exceeding (% by weight)	General characteristics
Tellicherry Garbled Special Extra Bold	4.75	0.5	3.0	11.0	Shall be dried mature berries of *Piper nigrum*, garbled, dark brown to dark black in colour, nearly globular with a wrinkled surface. It shall be free from garbled mould or insects or any other adulterant
Tellicherry Garbled Extra Bold	4.25	0.5	3.0	11.0	
Tellicherry Garbled	4.25 (50 % min) 4.00 (50 % max)	0.5	3.0	11.0	

Table 5. ASTA and ESA specifications of pepper (Pruthi 1980; Sivadasan 1999)

Specification	ASTA		ESA	
	Black pepper	White pepper	Black pepper	White pepper
Whole insects, dead (by count)	2	2	nil	nil
Mammalian excreta (mg kg^{-1})	2.2	2.2	nil	nil
Other excreta (mg kg^{-1})	11.0	2.2	nil	nil
Mould (% by wt/ count per g)	1.0	1.0	10^4 - 10^6	10^4 - 10^6
Insect defiled / infested (% by wt.)	1.0	1.0	nil	nil
Moisture content (% by wt.)	12.0	12.0	13.0	13.0
Ash (% by wt.)	7.0	3.5	7.0	3.5
Acid insoluble ash (% by wt.)	1.5	0.3	1.5	0.3
Volatile oil (% by wt.)	2.0	1.5	2.0	1.5
Extraneous matter (% by wt.)	1.0	0.5	1.0	1.0

without heat treatment, steam sterilization, thermal inactivation and ethylene oxide fumigation are the different methods for elimination of microorganisms (Pruthi 1991c). However, use of ethylene oxide is banned due to residual problems. Irradiated products have poor acceptance among consumers though the practice is accepted in 66 countries. A few companies in India have employed steam sterilization for spices including black pepper. An emulsion containing 25 per cent liquid paraffin, 9 per cent acetic acid, 12 per cent gum acacia and the rest water was found to be satisfactory, when applied at 15 to 20 cc per kg of pepper to control fungus and to impart glossiness. Application of the emulsion does not interfere with the grinding characteristics of pepper (Mathew *et al.* 1991).

Insects like *Lasioderma serricone*, *Stegobium paniceum*, *Laemophloeus minutus*, *Tribolium castanrum*, *Sitophilus oryzae* are reported in

Table 6. ESA specifications on microbial contamination (Nair 1999)

Constituent	Quantity (Maximum allowed)
Salmonella	Absent in 25 g
E. coli and coliforms	10^2 to 10^3 g^{-1} (max.)
Yeast and mould	10^5 to 10^6 g^{-1} (max.)
Aflatoxin	20 ppb

Table 7. ESA specifications on heavy metal contamination (Kalyanaraman 1999)

Constituent	Quantity (Maximum allowed)
Lead	10 ppm
Arsenic	5 ppm
Copper	20 ppm
Zinc	50 ppm

black pepper in storage (Pruthi 1991a, b). Inactivation methods involve irradiation, vacuum fumigation, thermal treatment etc. Mechanical washing with brushes or washing in running water followed by drying at the packing level reduce the microbial, insect and other contamination level to a great extent.

Value added products of pepper

Dehydrated green pepper

Thomas & Gopalakrishnan (1992) developed a process involving blanching and sulphiting combined with controlled drying and reduction of moisture to stabilize the green colour of pepper. Slightly immature green pepper is preferred for producing dehydrated green pepper. The cleaned pepper berries were subjected to blanching in boiling water for 10 to 30 minutes till the enzymes responsible for blackening the pepper are inactivated and polyphenols washed out of the berries. The pepper thus obtained was immediately cooled in water and subjected to sulphiting in potassium metabisulphite solution to fix the green colour. The sulphited berries were then washed and dried in a cabinet dryer at 50°C to get uniform green coloured berries. Boiling time depends on the maturity of the berries. Total heat inactivation of the enzyme was obtained after 10 minutes of boiling (Mathew 1994). Potassium metabisulphite has a phenolase inhibiting property and an ability to deter non-enzymatic browning (Varghese 1991).

Canned green pepper

The despiked and cleaned berries are immersed in water containing 20 ppm residual chlorine for about an hour. The berries are then immersed in 2 per cent hot brine containing 0.2 per cent citric acid, exhausted at 80°C, sealed properly and processed in boiling water for 20 minutes. Canned pepper is then cooled immediately in a stream of running cold water. It is reported that pepper harvested one month prior to maturity is ideal for the manufacture of canned green pepper (Narayanan *et al.* 2000).

Bottled green pepper

The manufacturing process consists of despiking the fresh green pepper berries of uniform size and maturity immediately after harvest followed by cleaning, washing and steeping in 20 per cent brine solution containing citric acid. This is allowed to cure for three to four weeks. The liquid is drained off and fresh brine of 16 per cent concentration together with 100 ppm sulphur dioxide and 0.2 per cent citric acid are added. The resulting product is stored in containers protected from sunlight (Pruthi 1997a).

White pepper

White pepper is the white inner corn obtained after removing the outer skin or pericarp of the pepper berries. It is preferred over black pepper in light-coloured preparations such as sauces, cream soups etc. where dark coloured particles are undesirable. It imparts pungency and a modified natural flavour to the foodstuff (Sudharshan 2000). Varieties like Balankotta and Panniyur 1, with large sized berries, are ideal for making white pepper.

The world demand for white pepper is about 40,000 MT, which is about 25 per cent of the black pepper produced worldwide. Major producers of white pepper are Malaysia, Indonesia and Brazil. Chief consumers of white pepper are west European countries, USA and Japan.

White pepper can be prepared using by any one of the following techniques (Pruthi 1980).

1. Water steeping and rotting technique (retting)
   a. from fresh ripe berries
   b. from dried berries
2. Steaming or boiling technique
3. Chemical technique
4. Decortication technique
5. Pit method (Varghese 1999).

The traditional method of preparation of white pepper is by retting (Anonymous 2001). If running water source is not available, the other alternative is to use fermentation tanks wherein the water is changed every day

(Nurdjannah & Dhalimi 1998; Sudharshan 2000). Retting converts only ripe and fully mature berries to white pepper whereas green berries turn into black eventually after drying. White pepper so produced had microorganisms and mould even greater than that of black pepper (Purseglove *et al.* 1981). Presence of black berries in white pepper is to the maximum of 5 per cent.

Another indigenous method of preparing white pepper is by pit burial method (Varghese 1999). Studies were taken up at IISR to evaluate the feasibility of pit method in the present pollution conscious situation. Mature (green), semi-ripe (20 to 40 per cent ripe or yellow) and fully ripe (red) berries were put into woven plastic bags and buried at 60 cm below the soil surface. It was found that fully ripe berries were converted into white pepper after 7 days whereas it required 14 days for converting green and yellow berries to white. The advantage with this method is that even mature berries get converted fully into white pepper. The percentage of black berries in white pepper was less than 0.2 per cent. This technology requires very less water and thereby less polluting in nature.

Another method patented by CFTRI involves blanching of green pepper berries in steam or hot water for 10 to 25 minutes to soften the skin (Lewis *et al.* 1969). Due to gelatinisation of starch, the powder from these berries was slightly dull in colour. However, the flavour quality was good and the microbial load was very low. The white pepper thus produced had stronger aroma than the traditional method (Risfaheri & Hidayat 1996a). Joshi (1962) developed a chemical process based on steeping whole dried black pepper in five times its weight of water for 4 days and treating with 4 per cent NaOH solution and boiling the mixture. This process did not take up commercially.

Prototypes of pedal and power operated pepper decorticators have been developed at RISMC (Risfaheri & Hidayat 1996b). The decorticating mechanism of disk type functions on the principle of pressure and friction. The white pepper produced by machine decortication had higher oil content and better and stronger aroma than the product of the traditional method. However, slight discolouration was observed due to the presence of phenol in the pericarp.

Conversion of black pepper to white pepper by selective grinding has been attempted by Thomas *et al.* (1991). The difference in behaviour of black skin and inner white core of dry black pepper to compressive forces was made use of to produce white pepper powder instead of the conventional retting and scrubbing. The process resulted in gray coloured berries. There is a loss of aroma due to friction during the decortication process. However, It saves time and avoids foul smell emanating due to fermentation and contamination. Another method of producing white pepper is by retting of dried black pepper. Due to fermentation, the skin gets softened in less than 12 days and is finally removed. This approach yields only a dark brown product and therefore demands supplementary bleaching to get white coloured pepper (Lewis *et al.* 1969).

Dry black pepper was deskinned using a bacterium (*Bacillus subtilis*) isolated from soil. The retting was carried out at a pH of 6.8 – 7.0 in a minimal nutrient medium with dry black pepper. Within 2 to 4 days, whole black pepper was deskinned. The advantages of this process are that the product is creamy white in colour, smooth and odour free (Thankamony *et al.* 1999).

The conventional retting method of converting ripe berries to white pepper yields the most superior product in terms of colour and fermented flavour (Sudharshan 2000). However, this process is season oriented and requires uniformly ripened berries. Conversion of harvested berries to white pepper gives a recovery of 22 to 25 per cent while the yield of black pepper is about 33 per cent. Hence, unless the price of white pepper is higher by atleast 30 per cent, it would not be economical to produce this product (Govindarajan 1977).

Ground pepper

Ground pepper is obtained by grinding pepper without adding any foreign matter. Grinding can be accomplished by employing equipments like hammer mill, pin mill or plate mill. The ground product is further sieved to the required size and packed. In order to reduce flavour loss in ground spices due to excessive heat produced during grinding, cooling arrangements are required. TNAU has developed a low temperature grinding system in which dry ice is used to cool the grinding zone of the mill (Anonymous 2001).

Cryogenic grinding by controlled injection of liquid nitrogen directly into the grinding zone helps in retaining more of volatile oils, improving fineness and minimum distortion in the natural composition of the powder (Pruthi 1980). The instantaneous evaporation of liquid nitrogen quickly chills the spice and the grinding zone of the mill. The chilled spice being brittle in nature gets comminuted into a fine powder. The evaporated liquid nitrogen expels the air inside the grinding zone and therefore the rate of oxidation of spice oils are brought down.

Pepper oil

The characteristic aroma of black pepper is due to the presence of volatile oil, which can be recovered by steam distillation or water distillation (Pruthi 1997b). The essential oil contains mainly a mixture of terpenic hydrocarbons and their oxygenated compounds. Industrial process for the recovery of essential oil involves flaking of the black pepper using roller mills or grinding into coarse powder and conducting steam distillation in a stainless steel extractor. The steam comes in contact with the ground pepper particles and vapourises the oil present in oil cells and rises up. The oil is recovered using an oil/water separator. Volatile oil of black pepper is slightly greenish with a mild non-pungent taste (Narayanan *et al.* 2000).

Oleoresin

Oleoresins are concentrated products obtained by extraction of ground pepper using solvents like hexane, ethanol, acetone, ethylene dichloride, ethyl acetate etc. The oleoresin produced is influenced by the solubility of the solvent used (Risfaheri & Nurdjannah 2000). Hexane gives very low yield because of low solubility of piperine in hexane and therefore not used for extraction of pepper oleoresin. Pepper is flaked to a thickness of 1 to 1.5 mm and packed in stainless steel extractors for extraction with the organic solvent. Normally, a solid to solvent ratio of 1:3 is employed and an extraction temperature of 55 to 60°C is maintained (Narayanan *et al.* 2000).

High yields of oleoresin (12 to 14 per cent) containing 19 to 35 per cent volatile oil and 40 to 60 per cent piperine are obtained with good quality pepper (Lakshmanachar 1993). Pepper oleoresin is a dark green viscous liquid with a strong aroma and pungent taste. Oleoresin contains the total pungency and flavour constituents of pepper. The largest use of pepper oleoresin is in flavouring meat.

Encapsulated spices

In the production of spray dried spices, the essential oils and or oleoresins are dispersed in the edible gum solution, generally gum acacia or gelatin, spray dried and then blended with a dry base such as salt or dextrose. As water evaporates from the sprayed particles, the gum forms a protective film around each particle of extractive. The protective capsule prevents the spice extractive from evaporating and from being exposed to oxygen (Pruthi 1980).

With the entry of more countries in pepper production and trade, India's position is becoming more and more competitive. It becomes imperative on the producer to make quality produce available at competitive prices. The present methods of processing at the farm level are not encouraging. Blanching combined with drying on clean surfaces improve the quality of pepper considerably. Though processors and exporters are well equipped with mechanical gadgets, they remain elusive for the common farmer. Therefore, systematic efforts have to be taken to mechanize the processing operations at farm level for cost reduction, better quality and value addition. It may be advantageous to install mechanical gadgets on community basis so that farmers can use them for a nominal fee. The existing threshers and other gadgets have to be improvised and refined for higher efficiency and low operating cost. Once the quality is lost at farm level, any amount of secondary processing will not improve the quality further.

Production of value added products at farm scale are needed to increase the returns of the farmer. White pepper, a value added product, can be easily prepared in the farm. Though, we are the leading producer of black pepper, the production is abysmally low. The traditional methods of preparation are far below satisfactory. Serious efforts are required for mechanization of processing operations in black pepper either in part or full. Product diversification is needed to increase the utilization of pepper, which at present has reached a stage of surplus. New products and recipes increase the consumption and thereby sustain the price. Value addition and product diversification help the country to withstand the competition and threat from other pepper producing countries.

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