Post Harvest Management of Garlic

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Abstract- *Garlic (Allium sativum L.), is one of the most perennial bulb crops of the lily family and is used as the spice or condiment throughout the country. India ranks second after China in world's garlic production and contribute 14% of the world area. Out of total spice production, garlic has the productivity of 1.8 MT/ha from an area of 2940 thousand hectares in 2010-2011. Fresh garlic is characterized with distinct aromatic odour which is seldom carried over into processed garlic. Variety, maturity level and conditions during the processing and storage affect the flavour and aroma intensity of garlic. The proper control of various steps during processing is the key to produce a garlic product with a flavour profile as close to fresh garlic. Further the value addition through packaging, storage and other post harvest technologies will be instrumental in substantially expanding the export basket of garlic and its derivative products.*

Keywords:- Garlic, Post harvest management, Techniques.

I. INTRODUCTION

Garlic (*Allium sativum* L.), the spice of the human life is one of the most perennial bulb crops of the Lily family (Liliaceae) which is grown all over the plains of India and is used as the spice or condiment throughout the country. Garlic is valued for its flavor and has commercial importance because of its wide medicinal value and application in food and pharmaceutical preparations (Sharma and Prasad 2001). The demand for garlic has grown at an increasing rate owing to its classification as a functional or health food that enhances nutrition and health along with imparting taste. Garlic contains allicin which has antioxidant, antibacterial and antibiotic properties (Augusti 1996).

Fresh garlic is characterized as having a distinct aromatic odor, which is seldom carried over into processed garlic (Pezutti and Crapsite 1997). Quality of garlic products is evaluated on the basis of their sensory characteristics, mainly color and flavor intensity or pungency. In 1844, German chemist wartheim isolated strong smelling volatile substances from steam distilled garlic oil and proposed the name allyl (from Allium) for the hydrocarbon group in the oil and allyl sulphur for the volatiles. German chemist F.W. Semmler, isolated diallyl disulphide ($C_6H_{10}S_2$), diallyl trisulphide and diallyl tetrasulphide from steam distilled garlic oil in the year 1892. Cavallito and baily (1944) isolated allicin from crushed garlic by aqueous ethanolic extraction followed by steam distillation. The flavor of garlic is attributed to the sulfur containing volatiles (allin). Allin is colorless, odourless, water –soluble amino acid present in the intact cells of garlic. By the action of an enzyme, allinase, allyl-S-cysteine sulfoxide (allin) is converted to diallyl thiosulfinates (allicin) and finally disproportionately to disulfides and thiosulfinates (Carson 1967). Allicin is the antibacterial substance of garlic and has the typical odour of garlic. It breaks down into the strong smelling constituents of garlic oil.

II. HISTORICAL EVIDENCE AND ORIGIN OF GARLIC

Garlic is one of the oldest and most popular spices in the world. In the old days, Egyptian and Indian cultures referred to garlic 5000 years ago and historical evidence shows that Babylonians found it 4500 years ago and Chinese by 2000 years ago. In 1858, Louis Pasteur reported that the garlic was antibacterial. In Ancient Egypt, the workers who had to build the great pyramids were served with garlic daily. Bible also mentions that Hebrews enjoyed their food with garlic. Now days, it is widely used to prevent atherosclerosis and high blood pressure. In early eighteenth century, France gravediggers drank a concoction of crushed garlic in wine which they thought is helpful in getting rid of plague. During, first and Second World War soldiers were fed with garlic to prevent gangrene.

But no such evidence is found on the varieties in early writings. Throughout its history some have speculated that softneck garlic was predominant type cultivated although evidence of what would be interpreted as a hard neck type was found in Egyptian tombs.

III. STATUS OF GARLIC PRODUCTION

India ranks second after China in world's garlic production and contribute 14% of the world area. According to National Horticulture Database (2011), the total production of spices in India during 2010-2011 was 5351 thousand million tonnes from an area of 2940 thousand hectares giving productivity of 1.8 MT/ha. The share of area under garlic is 200.60 thousand hectare with productivity of 53MT/ha (Fig. 1

and 2). During the same period, Punjab produced 63.5 thousand million tonnes with 18.4 thousand hectares under garlic production, giving the productivity of 3.5 MT/ha. Punjab ranks first with the highest yield at 14.73 tonnes / ha.

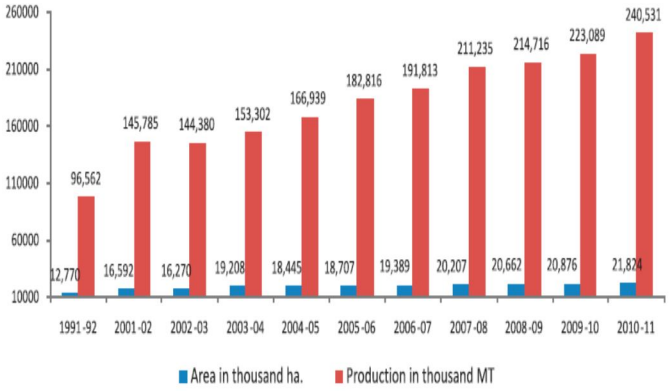

Fig.1 Area and Production Growth Trends for Horticulture Crops in India

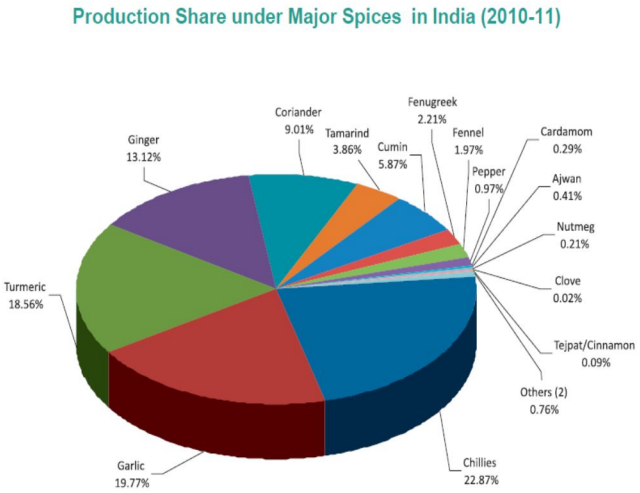

Fig. 2 Production share under major spices in India

IV. TAXONOMY OF GARLIC

Taxonomists have recognized at least four botanical varieties within *A sativum* L. namely, *A sativum* L. var. *sativum*, *A sativum* L. var. *ophioscorodon* (Link) Doll, *A sativum* L. Var. *pekinese* (prokh) Maekawa, and *A sativum* L var. *nipponicium* Kitamura. Hard neck, soft neck and creole varieties of garlic are grown worldwide (Fig. 3 and 4). Hard neck varieties have fewer cloves and have little or no papery outer wrapper protecting the cloves. Soft neck varieties are white, papery skin and multiple cloves that are easily separated. There are two types of soft neck varieties artichoke and silver skin. Creole variety has eight to twelve cloves per bulb arranged in circular configuration. While the bulb wrappers are very white, the clove covers vary from a beautiful “red” rose color to dark purple.

Fig. 3 Hard Neck Garlic

Fig. 4 Soft neck garlic

V. COMMON VARIETIES OF GARLIC GROWN IN INDIA

Various Agricultural Universities and ICAR institutes are presently working on the development of different varieties of garlic. Major work on garlic varieties has been taken up at National Horticultural Research and Development Foundation (NHRDF), HAU Hisar, PAU Ludhiana and IARI New Delhi. The varieties are HG -1, HG-2, Pusa Sel-10, LCG-1, ARU -52, VL-6, VL-7, Agrifound White (G-41), Yamuna Safed (G-1),Yamuna Safed -2 (G-50), Yamuna Safed -3 (G-282), Yamuna Safed -4 (G -323) and Agrifound Parvati (G-313). These varieties are mostly small bulbed and have number of smaller cloves except G-282 and Agrifound Parvati has bigger cloves.

Three major varieties grown in Punjab are Garlic -56-4, Punjab Garlic -1 and PG 17. Garlic -56-4 has central stalk, bearing 3-5 dark red skinned bulbils at the top. The cloves are bold and vary in number from 25-34 per bulb. Punjab Garlic -1 has dark green leaves and white cloves. The bulbs are uniformly large and attractive. PG 17 also has dark green leaves and white bulbs. The cloves are bold and vary from 25-32 per bulb. It is early maturing and takes 165-170 days for maturity.

VI. COMPOSITION OF GARLIC

6.1 Physical composition

Garlic cloves consists of a portion of the plant which is most commonly consumed called the 'head'. It is also called the underground storage structure. A head of garlic is composed of a dozen or more discrete cloves, each of which is a botanical bulb, an underground structure comprised of thickened leaf bases (Fig. 5 and 6). A garlic bulb is generally four to eight centimeters in diameter, white to pinkish or purple, and is composed of numerous (8-25) discrete cloves. The foliage comprises a central stem 25-100 cm tall, with flat or keeled (but not tubular) leaves 30-60 cm long and 2-3 cm broad. The flowers are produced in a small cluster at the top of the stem, often together with several bulbets and surrounded by a papery basal spathe; each flower is white, pink or purple, with six petals 3-5 millimeters long. The flowers are commonly abortive and rarely produce any seeds (Wikipedia)

Table1. Chemical composition of fresh peeled and dehydrated garlic

Constituent	Composition	
	Fresh peeled garlic cloves	Dehydrated garlic power
Moisture (%)	62.80%	5.20%
Protein (g) %	6.30	17.50
Fat (g)	0.10	0.60
Fibre (g)	0.80	1.90
Carbohydrate (g)	29.00	71.40
Calcium (mg)	0.03	0.10
Phosphorous (mg)	0.31	0.42
Iron (mg)	0.001	0.004
Vitamin A (I.V)	0.0	175.00
Vitamin C (mg)	13.00	12.00

6.2 Chemical composition of edible garlic (100g)

Garlic is rich source of carbohydrates, proteins and phosphorous. The fresh peeled garlic cloves contain 60-65% (wb) moisture, 6.30% protein, 0.10% fat, 1.0% mineral matter, 0.80% fiber, 29.0% carbohydrates, 0.03% calcium, 0.31% phosphorous, 0.001 iron, 0.40 mg/100g nictonic acid and 13mg/100g vitamin C (Brondnitz *et al* 1971).

6.3 Botanical composition

Garlic is a perennial that can grow two feet high or more. The most important part of this plant for medicinal purposes is the compound bulb. Each bulb is made up of 4 to 20 cloves, and each clove weighs about 1 gram. The parts of the plant used medicinally include fresh bulbs, dried bulbs, and oil extracted from the garlic. The Bulb, 12 inches to 18 inches tall (30-45 cm), 9 inches to 12 inches in spread (22.5-30 cm).

VII. MATURITY INDICES FOR GARLIC

` Maturation is the stage of development leading to attainment of physiological maturity (when a plant or plant parts will continue ontogeny even if detached) or horticultural maturity (when a plant or plant parts possesses the pre-requisites for utilization by the consumers).

Maturity indices form an important part in the process of post harvest management. It helps in deciding the harvest time of the crop and to ensure that the crop is ready to be sold in market, possessing desirable eatable qualities. But sometimes, the crop is picked at the working stage of maturity leading to the development of physiological disorders and shortened shelf life.

So, for selecting the harvest maturity of the horticultural crops, it should be kept in mind that the harvested commodity has its peak acceptable quality (i.e. non-toxic, size, appearance and flavour with adequate shelf life) (Thompson, 1996). Garlic can be harvested at different stages of development for specialty markets, but most of the garlic is harvested, when the bulbs are well mature. Harvest occurs after the tops have fallen and are very dry. Garlic is grown in rich soil, so it is necessary to break over the tops to prevent too much top growth. For the garlic planted early in the fall, a cover crop of oats can be sown at planting time to provide winter protection for the young plants. In cold season, a layer of organic mulch is applied which stabilizes the young plants preventing them from frost heaving, cold injury or premature growth.

VIII. GARLIC STORAGE

Garlic and its dried products are suitable for storage under low humidity conditions. Sprouting occurs if the storage is done at intermediate temperatures. Moreover the variety of the garlic affects the potential storage life. Storage period determines the conditions to be employed for commercial storage. Garlic can be stored in good condition for 1-2 months at ambient temperatures (20-30°C) under low relative humidity (< 75%)(Table 2). But under these conditions, bulbs will eventually become soft, spongy and shriveled due to water loss. For long term storage, garlic is best maintained at temperatures of -1°C to 0°C with low relative humidity (60-70%). Also good air flow is necessary to prevent the moisture accumulation. Under, these controlled conditions, potential storage duration increased to 9 months.

Table2. Temperature and RH recommendations for potential storage of garlic.

Commodity	Temp		R.H.	Potential storage duration
	0°C	°F	%	
Garlic	0°C	32	70	6-7 months
	28-30	82-86	70	1 month

Garlic looses dormancy, which is indicated by the sprouting of bulbs (Table 3). It occurs at the storage temperatures of 5-18°C. Also high humidity will favor the mold growth. While storage, it must be kept in mind that garlic should be stored separately to prevent the transmission of odor to other products.

For bulk storage of garlic, ventilation systems should be designed to provide air into the store room from the bottom at the rate of 2 cubic feet per minutes per cubic feet of produce (Fig.7). Rows of containers should be stacked parallel to the direction of the flow of air and should be spaced six to seven inches apart.

Table3. Rates of respiration of garlic

Temp. (°C)	0°C	5°C	10°C	15°C	20°C
Intact bulbs (ml Co_2/kghr)	2-6	4-12	6-18	7-15	7-13
Fresh peeled cloves (ml Co_2/kghr)	12	15-20	35-50		

IX. POST HARVEST PROCESS

9.1 Principles involved in post harvest technology and its status in India

In order to protect the herbs and the spices and to retard the microbial or other physiological activities, the post harvest processing, storage and handling is carried out. These all post harvest techniques include the storage at controlled temperature, moisture content, relative humidity etc. Further, the processing of the raw material could also help in extending the shelf life of the product.

It has been reported that the post harvest management technology in case of the horticultural produces is inadequate. Also the processing aspect is not as flourished as compared to the other crops. Moreover, the constraints faced by the post harvest industry of horticultural crops make the industry non-productive. Various constraints are as prohibitive costs and lack of traditional taste suiting the Indian dietary habits lowers the demand of processed products resulting in sluggish growth (Joshi and Pandey, 1999). The other factors which restrict the establishment of such industrial are marketing limitations, financial and fiscal constraints. Moreover, lack of proper research or development, which is a major pillar in post harvest management of horticultural crops.

9.2 Thrust areas

The involvement of contract farmers of horticultural crops as practiced by the multinational companies can benefit the consumers & farmers. Determination of the maternity indices for the harvesting could present the post harvest losses (Kumar and Gopinath 1995). Awaring the consumers for the use of medicinal plants in different food products to provide more nutritional value and to fight against the chronic diseases. Developing biotechnological approaches in horticultural crops for the storage and processing qualities could also alleviate the post harvest shelf life (Sharma and Joshi 1990).

X. IMPORTANCE OF GARLIC PROCESSING

Processing of garlic is one of the most important operations. It triggers the formation of cascade of compounds that do not already exist in raw garlic. Therefore, processing is the key to increase the benefits of garlic and to decrease its toxic effects. A variety of sulphur containing compounds, work synergistically in their contribution to the benefits of garlic. Moreover, garlic is a herb and has been used as a medicine to prevent and treat wide range of diseases. The fresh clove or supplements made from the clove are used in pharmaceutical operations.

XI. MISCELLANEOUS POST HARVEST TECHNOLOGIES

11.1 Garlic powders

Dehydrating the fresh garlic cloves into powder is the most primitive method to preserve the garlic. Garlic power is used as a flavoring agent for condiments and processed foods. While preparing the powder, garlic cloves are sliced, crushed, dried and ground into power. The average content of allin present in garlic is 0.8%, however, raw garlic contains around 3.7 mg/gm of allin.In India small scale industries use tray drier for drying the garlic cloves. The moisture content of garlic cloves is reduced from initial moisture content of about 60-65% (wb) to a safe level of 6% (wb). The dehydration of the garlic cloves using tray dryer is both energy intensive and time consuming process. It takes about 9-10 hours to dry garlic cloves in a single stage in a tray dryer at the temperature of 70° C.

Fluidized bed drying of garlic cloves has also been attempted but was not effective in reducing the energy consumption and the drying time.

Sharma and Prasad (2001) analyzed dried garlic cloves with hot air and combined microwave hot air drying methods. The combined hot air – microwave drying experiments were carried out with 100 g of sample at temperatures of 40°C, 50°C, 60°C and 70°C at air velocities of 1.0 m/s and 2.0 m/s. For comparison of hot air drying, the same sample sizes were taken for drying air temperatures and air velocity of 60°C and 70°C and 2.0 m/s respectively. They reported that combined microwave- hot air drying resulted in reduction in the drying time to an extent of 80-90% in comparison to conventional hot air drying and also resulted in superior quality of the final product.

Bisnoi *et al* (2008) carried out the experiment to evaluate the dehydration characteristics of pretreated garlic by using different methods. The effect of pretreatments viz. control(without treatment), hot water blanching at 80-85°C for 5 min and sample treated with 0.5% sodium metabisulphite for 20 min and dehydration methods namely open sun drying, solar cabinet drying, electric tray drying and microwave oven drying was studied. The results of the study showed that the product quality of blanched sample foe 55°C and sodium metabisulphite treated sample for 65°C in electric tray drier was best.

11.2 Garlic paste

Paste is one of the alternatives that would retain the delicate and fresh odor of garlic. It is prepared with garlic bulbs of 16 weeks maturity and was stored at 25°C for one month before processing. Cloves were then dried in a tray drier at 40°C for 30 minutes to facilitate the peeling process. After peeling the cloves were blanched at 90°C for 15 minutes in water (Rejano *et al* 1997) followed by grinding in a laboratory size grinder. In order to increase the total solids, desired quantity of sodium chloride (w/w) was added. The final pH was adjusted to 4.1 by adding 30% citric acid (w/v) solution (Ahmed J *et al* 2000).

Lukes (1986) indicated that amino acid S (l-propenyl) cysteine sulfoxide was responsible for the development of green color and recommended that garlic bulbs should be stored above 23°C for at least one month to prevent greening of the products. Kang and Lee (1999) studied that the large and active surface area of garlic paste accelerates surface discoloration, including enzymatic and non enzymatic browning, moisture and flavour losses, microbial spoilage and poor quality. Bae and Lee (1990) observed the browning of chopped garlic as a result of oxidation of phenolic compounds, such as pyrogallol and garlic acid, by polyphenoloxide into quinine substances further underwent condensation and polymerisation to produce highly colored products. The application of reducing agents (ascorbic acid, cysteine and flavonoid glycosides) appeared to retard the darkening of plant tissue.

Rejano and others (1997), stated that the flavour of the processed garlic is notably free from the typical pungent flavour of fresh law garlic. The pungent character of raw garlic is attributed to alkenyl thiosulfinates generated by the action of allinase, which is activated on cutting the garlic clove. Blanching with hot water, steam or electromagnetic energy was used as a treatment to deactivate allinase activity responsible for flavor alterations and tissue softening.

11.3 Garlic oil

Garlic oil is another important preparation which is provided as a result of distillation process of raw garlic. Garlic essential oil is obtained by steam distillation of garlic. The essential oil content of garlic cloves is 0.2-0.5% & consists of variety of sulfides. Such as diallyl disulphide and diallyl trisulphide. The specific gravity and refractive index of garlic oil at 25°C is 1.091-1.098 and 1.5740-1.5820 respectively.

Sowbhagya *et al* (2009) investigated that the oil yield in case of cellulose, pectinase, protease and viscozyme pretreatment was in the range of 0.39 – 0.51% as against 0.28% in a control sample by steam distillation and in the range of 0.45- 0.57% by hydrodistillation as against 0.31% in a control sample. Profiling of the garlic oil thus obtained was carried out by GC-MS. Di-2 –propenyl trisulphide (52%) along with corresponding di and tetra sulphides (11% and 5%) constituted the major portion of the oil. The other major flavour compounds identified were methyl 2 – propenyl trisuphide (11.8%), vinyl dithins (9.9%) and dithianes (4.1%). The studies demonstrate that enzymes facilitate the extraction of garlic oil resulting in an increase in the yield of the oil with little change in physiochemical properties of the oil.

11.4 Garlic oil macerates

Two types of the macerate products are in market and both are packaged in soft gel capsules. One is made by simply mixing garlic. Flavoring powder with vegetable oil. Another one is made by grounding raw garlic in vegetable oils. Both products are rich in fat and are not suitable for daily supplements.

11.5 Garlic extract

Aged garlic extract is a totally balanced garlic supplement containing large amount of essential water soluble compounds and small amounts of oil soluble. Several patents have been registered to prepare garlic juice or extract. Lazarev Ivanova (1969) patented the method of obtaining 2-component extract of garlic. In this process garlic is cooled and ground for aqueous extraction to yield enzyme extract called the first component. The residue is further extracted with liquid CO_2 to give enzyme free extract called second component. The two components are mixed together prior to being added to food products.

Kimizuka *et al* (1988) patented a flavour enhancing seasoning containing deodourised garlic extract and the process. Blanching garlic, and extracting the blanched product with water, prepared the seasoning. The extract produced was deodorized and concentrated to provide a seasoning additive that dramatically improved the flavor fullness, depth and duration.

11.6 Storing Garlic in wine or vinegar

Peeled garlic cloves can be preserved by dipping in wine or vinegar, which will act as preservating agents. A dry white or red wine is suggested or vinegar. The entire garlic/liquid mixture must be stored in refrigerator to prevent the mold growth. In general, alcohols are known to denature proteins and are useful in inhibiting allinase. It has been determined that the utilization of combination of methanol and ethanol at 40% allinase was very active. Moreover concentrating the alcohols up to 995 cause a precipitous decrease in allinase activity (Lawson and Wang 1994 as cited in Koch and Lawson 1996)

11.7 Storing garlic in oil

Garlic in oil must be prepared following guidelines and must contain citric or phosphoric acid to increase the acidity. Garlic in oil mixture must be stored in freezer otherwise ambient room conditions would provide the conditions for production of botulism toxin.

XII. OTHER PROCESSING OPERATIONS

12.1 Peeling

Garlic peeling is one of the most important and essential key unit operations prior to any subsequent processing activity. During garlic peeling the thin membrane skin is to be removed off from the segments. The various methods for peeling of garlic are as follows. Lye peeling requires caustic soda and supply of water and steam. In this method, garlic is immersed in hot caustic soda solution in the lye peeler itself followed by vigorous water rinse to remove the chemicals adhered to the skin. The cloves are then neutralized in acid bath and trimmed to give perfect finish. Another traditional method of peeling involves the submergence of cloves in warm water for 5-10 minutes. This makes the outer skin soft and can be easily peeled by hand. In the oven method of peeling, garlic is placed in oven for 5-10 seconds .the root is then cut and skin slides off easily. Flame peeling is another tedious method in which garlic is brought into direct contact with the live flame .High temperature burns the outer skin and can be easily removed.

The abrasion gadgets developed earlier were found infeasible as the cloves were crushed. The skins of peeled cloves adheres to the lining material and imparts smoothness to the abrasive surfaces in due course of time, thereby adversely affect the performance (Mudgal *et al*., 1998). Sakata (2002) patented the garlic disintegrating and peeling apparatus which had a hollow main body provided with a rotary disk having a plurality of vertical rods to form a step on the upper faces, a cylindrical peeling vessel having an uneven face and granular grinding face on the inner side face and a driving means to drive the rotary disk.

Mudgal (2005) reported that the compressed air based principle and abrasion based gadgets for garlic peeling were found infeasible as thin skin peel removed from cloves gets adhered to the abrasive surface and thus renders it quite inefficient within short span. Nagarajan (2006) developed a garlic peeling machine with a capacity 200 kg/h. The pressurized air pushed the garlic entering the peeling chamber from the big blower to the rotating blade since the blades were rotating, they hit the garlic towards the serrated wall of the peeling and it gets peeled.

Mudgal V D and Chapawat (2008) tested the performance of an air-assisted Garlic Clove Peeler. The height of the peeling chamber (400 mm), bed depth (60 mm), air jet pressure (10, 15 and 20 kg/cm2) and position of air jet (60, 80 and 90 mm) were taken for evaluation. The peeling efficiency was observed to be 97-98%.

Mudgal and Champawatt (2011) developed a low cost garlic clove peeler was developed consisting of a 130 mm diameter, 400 mm long peeling chamber mounted on a MS angle frame. The top portion of the pressure chamber was connected to 40 mm diameter reducer to separate thin husk from the peeled material.

Majunatha *et al* (2012) developed a power operated garlic peeler having a cylinder concave mechanism. An experimental garlic peeler having cylinder covered with 10 mm thick rubber was fabricated and evaluated for its performance with crop machine parameters viz., cylinder speed (29, 36 and 42 rpm), cylinder concave clearance (8, 10 and 12 mm), moisture content (23%, 27.7%, 33.4% and 40.5% wb) and concave mechanisms.

12.2 Roasting of garlic

Roasted garlic, which has become popular in recent years, is sweet to the taste and is used as delicious on bread or crackers as an appetizer or served as a vegetable side dish. To prepare roasted garlic, leave the head whole and cut off the tip of the head, exposing the cloves. Allow one-half to one head per person. Put the head (or heads) in a baking dish or wrap them in aluminum foil, sprinkle with olive oil or pat with butter, and season with a little salt and pepper and some fresh or dried thyme if desired. Bake at 350 °F until very soft and tender (about 45 minutes to 1 hour). The roasted garlic cloves can be easily squeezed from their skins and spread with a knife.

12.3 Freezing of garlic

Garlic can be frozen in a number of ways.

Chop the garlic, wrap it tightly in a plastic freezer bag or in plastic wrap, and freeze. To use, grate or break off the amount needed. Freeze the garlic unpeeled and remove cloves as needed. Peel the cloves and puree them with oil in a blender or food processor using 2 parts oil to 1 part garlic. The puree will stay soft enough in the freezer to scrape out parts to use in sautéing. Freeze this mixture immediately - do not store it at room temperature. The combination of the low-acid garlic, the exclusion of air (by mixing with oil), and room temperature storage can support the growth of *Clostridium botulinum.*

XIII. CONCLUSION

Garlic is an important crop which is used for flavouring and seasoning various vegetables and dishes. The crop deteriotes in quality of stored at ambient conditions, so the role of post harvest management of the horticultural crops arises here. So, the main focus should be to prevent the spoilage and have maximum utilization of the crop in a nutritious and safe manner. The post harvest technology should comprise all the methods right from the field to consumer.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Department of Processing and Food Engineering, Punjab Agricultural University for providing the assistance in compiling this review paper.

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