EFFECT OF PRE TREATMENTS AND CURING METHODS ON THE QUALITY CHARACTERS OF PROCESSED CARDAMOM

(*Elettaria cardamomum* (L.) Maton)

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(2010-12-107)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Effect of pre treatments and curing methods on the quality characters of processed cardamom (Elettaria cardamomum (L.)Maton)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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DEDICATED

TO

MY FAMILY

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LIST OF ABBREVIATIONS

%	-	per cent
CD	-	Critical difference
cm	-	centimetre
cm/h	-	centimetre per hour
et al	-	Co workers
Fig.	-	Figure
g	-	gram
Kg	-	kilogram
m	-	metre
m/s	-	metre per second
mg	-	milligram
min	-	minutes
ml	-	milliliter
mm	-	millimeter
^{0}C	-	Degree Celcius
s	-	seconds
ppm	-	parts per million
i.e.	-	That is
viz.,	-	namely
CRD	-	Completely Randomized Design

LPG	-	Liquid Petroleum Gas
ICAR	-	Indian Council of Agricultural Research
CFTRI	-	Central Food Technology Research Institute
LDPE	-	Low Density Poly Ethylene
HMHDPE	-	High Molecular High Density Poly Ethylene
IISR	-	Indian Institute of Spice Research
AGEB	-	Alleppey Green Extra Bold
CGEB	-	Coorg Green Extra Bold
AGS	-	Alleppey Green Shipment
GLC	-	Gas Liquid Chromatography
PET	-	Poly Ethylene Terephthalate
USRDA	-	United States Recommended Daily Allowance
IR	-	Infrared Spectroscopy
SFME	-	Solvent Free Microwave Extraction
USDA	-	United State Department of Agriculture
MRL	-	Maximum Residue limit
EPA	-	Environmental Protection Agency
α	-	Alpha
β	-	Beta
γ	-	Gamma
PEG	-	Polyethylene Glycol

NAA	-	Naphthalene Acetic Acid
CO_2	-	Carbon dioxide
EHEC	-	Entero Hemorrhagic *Escherichia Coli*
AOAC	-	Association of Official Analytical Chemists
TIC	-	Total Ion Chromatogram
FT IR	-	Fourier Transform Infrared Spectrometer
RRI	-	Relative Retention Indices
VF	-	Varian Factor
NIST	-	National Institute of Standards and Technology
CFR	-	Code of Federal Regulations
GC MS	-	Gas Chromatography Mass Spectrometry
WHO	-	World Health Organization
ASTA	-	American Spice Trade Association
IOSTA	-	International Organization of Spice Trade Associations
NOEL	-	No Observed Effect Level
PMTDI	-	Provisional Maximum to Tolerable Daily Intake
DASH	-	Dietary Approach to Stopping Hypertension
USEPA	-	United States Environmental Protection Agency

Introduction

1. INTRODUCTION

Spices constitute an important group of agricultural commodity that is considered indispensable in food flavouring industry, in pharmaceutical industry, perfumery and cosmetic industry. India is the largest producer, consumer and exporter of spices in the world. Cardamom known as "Queen of spices" is one of the most important and highly priced spices. Indian cardamom occupies an enviable position in the global spice market due to its unique flavour and aroma. In India cardamom is mainly cultivated in Kerala, Karnataka, and Tamil Nadu. On an average, Kerala accounts for 76 percentage of total production in India (Joseph, 2010). In Kerala cardamom is mainly cultivated in Idukki district.

Cardamom industry in India recorded unprecedented achievements in the export earnings, domestic prices, and export unit value realization. The important quality parameters of cardamom in the export market are colour, flavour, aroma, size of capsule, weight per specified volume and freedom from microbial, insect and filth contaminations (Govindarajan *et al.*, 1982). Green colour of cardamom capsule is an important factor in the consumer market which makes a visual preference for the product. Moreover green colour indicates its freshness. The retention of green colour thus becomes one of the important aspects in the processing of cardamom. The present recommendation for pre treatment of cardamom capsules involves soaking the capsules in sodium carbonate (2%) solution for 10 minutes prior to drying for better retention of colour and to prevent mould growth (Kuruvila *et al.*, 2009). The use of sodium carbonate (2%) for 10 minutes resulted in large percentage of splitting of capsules as observed in the initial experiment to pre fix the concentration and time of treatment. In this circumstance a new experiment was laid out to standardize the pre-treatment chemical, its concentration and the time of dipping the capsules.

The fresh cardamom capsules collected is cured to produce the spice of commerce. Curing/drying is the most important unit operation that determines the quality parameters of cardamom. The farmers in the Idukki district usually cure cardamom either by conventional method or by using modern artificial driers. Hence the experiment had been framed to cure the pre- treated capsules both under conventional drier and under modern artificial drier.

Thus the present investigation entitled "Effect of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardamomum* (L) Maton)" was carried out with the following objective: -

1. To standardize pre treatment chemical, its concentration, and time of dipping of cardamom capsules in chemical solution to enhance green colour of cured cardamom.

2. To standardize better pre treatment chemical both under conventional curing and modern curing by analysing physical, chemical and sensory parameters.

3. To evaluate whether the pre treatments and curing methods affect the cardamom capsules by analysing physical, chemical and sensory parameters.

4. To evaluate whether the flavour profile is influenced by pre treatments and curing methods subjecting to the essential oil analysis using Gas Chromatography/Mass Spectrometry (GC/MS) technique.

Review of Literature

2. REVIEW OF LITERATURE

The name "India" conjures up a vision, in the minds of foreigners, as a land of spices. Spices constitute an important group of agricultural commodities, which since antiquity; have been considered indispensible in the culinary art for flavouring foods. Spices are used in pharmaceutical, perfumery and cosmetic industries since they possess antioxidant, antiseptic, colouring, preservative and antibiotic properties. Besides, they also play quite significant role in our Indian national economy and also in the national economics of various spice producing, exporting and importing countries of the world. Five major spices (black pepper, cardamom, chillies, ginger and turmeric) together account for about 75 to 89 percentage of the total annual foreign exchange earnings from spices (Pruthi, 2001). Cardamom is an important spice commodity of international commerce ever since the ancient Greek and Roman period. More than 90 percent cardamom of international commerce, both small as well as large, originated in India (Madan, 2002).

Cardamom (*Elettaria cardamomum* (L.) Maton), the small cardamom acclaimed as the "Queen of spices" is the true cardamom belonging to the family zingiberaceae under the order scitaminae. It is one of the most important and highly priced spices, next only to saffron. Cardamom of commerce is the dried capsule of *Elettaria cardamomum* (L.) Maton (Pruthi, 1987). Though by definition processing does not involve harvesting, one cannot produce a good product from badly harvested material. Correct harvesting techniques are said to be the most important factor in the production of high quality final product. Thus processing of cardamom requires close monitoring right from harvest to the drying and final grading.

The present study intends to find an effective pretreatment and curing method for cardamom which can retain green colour and quality aspects. The chapter reviews the literature on the pre treatments, curing methods, their effects

on the physical, chemical and sensory parameters of cardamom. The literatures on the flavor profile of essential oil of cardamom and the residue of the chemicals treated on the cardamom capsules are also reviewed.

2.1. HARVESTING OF CARDAMOM

According to Krishna (1979) harvesting of cardamom is the most important operation that merits the immediate attention of cardamom growers. It is reported that proper harvesting improved the quality and quantity of the produce. Nybe *et al.* (2007) reported cardamom plants started bearing fruits (capsules) from second year after planting and satisfactory yield obtained from third year onwards. The harvesting season started by August and continued to December, peak harvest being during October -November. Capsules were harvested at an interval of 15 to 20 days at Karnataka and 30 days in Kerala and harvesting would be completed in seven to eight rounds. Fruits that were just ripened or physiologically mature (at the black seeded stage) were picked by experienced workers. If capsules were immature, they would have a wrinkled appearance on curing and if they were fully ripe would split on curing and would develop a yellow colour.

Pruthi (1993) reported that sustained yields could be obtained from third year onwards upto tenth or fifteenth year, depending on the type cultivated, after which the plants become exhausted. In India flowering commences in April and May and continues until July and August usually, although some flowers might be seen almost throughout the year. Zachariah and Korikanthimath (2002) reported that two types of pickings were usually practiced in cardamom - light picking and hard picking. In the light picking only mature capsules were harvested while in hard picking semi mature crop were also removed. This might reduce the curing percentage but it could increase the picking average, secure green coloured capsules and also reduced the chance of fruit drop and splitting in the field. When cardamom capsules were ripe it could be easily removed from the stem of plant without too much force. The harvester should start harvesting at the

base of each stem and move up the stem, taking off capsules that easily fall off without pulling. The capsules that do not fall off easily should be left on the plant to ripen (Ali, 2002).

Krishna (1979) observed that when light picking was done, the gap between picking rounds could be maintained at 20/30 days and for hard picking this gap could be kept between 30/45 days. The choice of picking depended, at times, on the availability of labour. According to Zachariah and Korikanthimath (2002), 2860 ripe capsules weighed 1kg while 3330 physiologically mature cardamom capsules and 5000 immature capsules each weighed 1kg. The percentage recovery was 29 percent in ripened stage, 24 percent in physiologically mature and 14 percent in immature stage. Hence it was reported as ideal to pick cardamom at the just ripened stage or physiologically mature stage. At this stage the seeds inside the capsules would be black in colour. Harvesting at the correct stage of maturity was essential to produce high quality cardamom capsules. The post harvest operations of cardamom involved washing, curing, drying, cleaning, polishing, sorting, grading and packing of capsules (Nybe *et al.*, 2007).

2.2. WASHING OF CARDAMOM CAPSULES

The capsules immediately after harvest were washed in water to remove adhering soil (Nybe *et al.*, 2007).

2.3. PRE TREATMENT OF CARDAMOM CAPSULES

Different treatments were tried to retain green colour of cardamom, in which soaking green capsules immediately after harvest in two percent sodium carbonate solution for ten minutes followed by subsequent drying was found to protect green colour. This alkali treatment had been claimed to inhibit colour loss during drying operation and to extend colour retention during subsequent storage from the conventional three months period to ten months (Natarajan *et al.*, 1967,

1968). Pruthi (1993) reported that the quality of cardamom was to some extent judged by the green colour.

Rao *et al.* (1987) reported that storing of cardamom capsules for more than six months led to fading of colour if it was treated with alkali solution (washing soda). According to Kachru *et al.* (1988), the cardamom capsules treated with alkali might be again washed once or twice in fresh water and the water should be completely drained off before drying the capsules. In various trials conducted earlier, it was found that presoaking (quick dip) of capsules in hot water at 40^0C and dipping capsules for 10 minutes in two percent sodium carbonate had helped in better retention of green colour of cured capsules. Dipping capsules in hot/warm water at lower temperatures *viz.*, 30 and 35^0C also were tried. Additives like sodium carbonate (two percent) in warm/hot water (particularly at 35^0C) helped to increase green colour of capsules. Dipping in hot water might arrest the activity of certain hydrolytic enzymes. Volatiles extracted from capsules presoaked in hot water and sodium carbonate solution were subjected to gas-liquid chromatography (GLC). The results indicated that there were no significant changes in oil profile due to hot analysis of water or sodium carbonate treatments (Anonymous, 1991).

Presoaking of capsules in copper formulations and chemicals like NAA, IAA, GA and Magnesium sulphate helped to retain more chlorophyll compared to other treatments tried. However, when presoaking time was extended to 60 minutes, significant depletion of chlorophyll was observed in all, except in ascorbic acid treatment. Other treatments *viz.*, urea, 2,4-D and cycocel at 100 ppm each, kinetin at 10 ppm, glycerol at five percent and polyethylene glycol at five percent recorded either no effect or marginal negative effect on the stability of chlorophyll (Anonymous,1991).

2.4. CURING OF CARDAMOM CAPSULES

Babu *et al.* (1983) stated that the capsules should be immediately dried to retain the original colour at which they were harvested otherwise the colour might tend to change from green to golden yellow up on ripening. This should be especially significant in case of Malabar variety, popularly grown in Karnataka. It retained the golden hue even after drying. Vadiraj (2004) defined cardamom curing as process in which moisture content of freshly harvested cardamom capsules was reduced from 80 percentage to 11-12 percentage at an optimum temperature of 45-55^0 C to retain its green colour and volatile oil to a maximum extent.

The effect of chemical pretreatment and drying temperatures on the common quality of cardamom was studied. The pre drying treatment of two percentage sodium carbonate and drying temperatures of 35^{0}C, 45^{0}C and 55^{0}C was used for drying continuously or in stages. Percent chlorophyll removal, total oil and essential oil content, percentage splits and percentage out-turn were determined in chemically pre treated and non-treated cardamom. The chlorophyll content was found to be best retained in the chemically treated cardamom at 45^{0}C drying temperature. The loss in total oil content was minimum for the chemically pre-treated cardamom at a drying temperature of 45^{0}C, while maximum terpenoids were retained at 45^{0}C in the untreated cardamom. The percentage of splits was lowest for the untreated product continuously dried at 45^{0}C and the percentage of out-turn was highest for the chemically treated cardamom at 45^{0}C drying temperature. The recommended treatment conditions to meet trade quality standards were thus found to be 45^{0}C drying temperature and chemically pretreated and continuously dried cardamom (Ilangantileke *et al.*, 1993). Balakrishnan *et al.* (2002) observed drying of cardamom as one among the unit operations found to influence the green colour of the end product mainly, the total chlorophyll content considered to be one of the top most quality characters.

2.4.1. CONVENTIONAL CURING

The low thermal efficiency of existing curing chamber was reported by Kishore and Rastogi (1987) and they had developed a mathematical model to study the heat transfer. According to Palaniappan (1989) proper drying or curing was needed to bring out the aromatic flavor of cardamom for longer preservation. The most commonly adopted practice to dry cardamom was reported as smoke house or curing chamber method.

Curing is effected through conventional curing chambers in the hill ranges of Kerala, Karnataka and Tamil Nadu. A survey undertaken in Kerala, Karnataka and Tamil Nadu by Palaniappan (1982) revealed that the thermal efficiency of conventional curing chambers ranges from three percentage in the first generation chamber which meant that only 3 to 16 percentage of the firewood fed was actually used for drying cardamom. It had been found that 12 million Kg of firewood was wasted annually in conventional chambers. A modification to curing chamber had been suggested by Riva *et al.* (1988) which suggested the involvement of air holes and one or two exhaust fans. The size and number of required air holes could be calculated from the volume flow rate needed in the chamber while the diameter of the flue pipe had to be between 0.2 to 0.3 m. The fan operation had to be regulated depending on the moisture condition of air in the chamber. The financial gain expected per year by the suggested modifications was around three to four times the investment cost.

2.4.2. MODERN CURING

Varkey *et al.* (1980) conducted studies on artificial drying of small cardamom at Regional Research Laboratory, Trivandrum and concluded that green cardamom could be dried in a bin drier upto a bed thickness of 20 cm with a drying temperature of 50 to 60^0C. The scientists developed a mechanical drier consisting of a centrifugal blower, electrical furnace, ducting with arrangements

to distribute the flow of hot air uniformly and a drying chamber capable of loading 120 Kg of fresh cardamom capsules with an air velocity of 60cm/h and temperature adjusted at 50^0C. The drier took 22 hours for complete drying and the dried capsules had been found to be acceptable to the trade in superior green colour, flavor and appearance. A comparison of different curing system in large cardamom was done by Karibasappa (1987). According to him, the quality of cured cardamom in traditional bhatti system was inferior while the quality of the produce from the flue pipe and CPCRI dryers were good with original colour and flavor. The keeping quality of the produce from flue pipe system and CPCRI driers were found to be better compared to the traditional bhatti system.

Cardamom Research Station, Pampadumpara had developed a solar drier for the drying of cardamom (Vijayan, 1974). Patil (1987) reported the use of a direct type of solar drier developed for copra drying for curing of cardamom. A comparative performance and economic analysis of various drying systems available at that time for large cardamom was also carried out by Annamalai *et al.* (1988). The solar drier (direct type) with radiation shield of red transparent glass (which helped in cutting off the radiation responsible for discolouration or bleaching) was effective in sun drying of the green cardamom without changing the colour. Solar driers with a capacity of 25-35 Kg that took 30-36 hours were also reported but not very popular due to the non availability of sufficient sunlight in the plantation area during the entire harvesting period (Rao *et al.*, 1987). According to Jose (2010) in comparison with open sun drying, solar driers were fast and drying was completed in three days instead of five days.

Patil (1987) also observed that the time required for curing in kiln driers varied from 24 to 36 hours while it was 12 to 24 hours in electrical driers. In electrical driers the temperature was kept at 50 to 65^0C and the air circulation was done by an elecrtrically operated fan. Rao *et al.* (1987) reported that many models of electric driers were also available but the interrupted supply and high costs of electricity were the limiting factors for its adoption. University of Agricultural Sciences, Bangalore had designed and developed a mechanical drier

for cardamom consisting of a drying chamber, blower with motor and electrical heating unit, the capacity being 10 Kg dried cardamom and it took 14 hours to reduce moisture content of cardamom from 79 percentage to 19 percentage (Kachru *et al.*, 1988).

Drying experiments were carried out in Regional Research Laboratory, Trivandrum, aimed at drying the fresh cardamom using a laboratory model fluidized bed drier. Thomas *et al.* (1991) reported that cabinet drier took eleven and half hours to reduce the weight of cardamom from 100 g and the fluidized bed drying took only 52 min, 80 min, 120 min, 250 min and 280 min respectively at temperatures 90^0C, 80^0C, 70^0C, 60^0C and 50^0C. A study was undertaken at Tamil Nadu Agricultural University to determine the drying characteristics of cardamom under thin layer drying and fluidized bed drying to optimize the drying parameters of drying cardamom. It was concluded that drying of cardamom required a bed thickness of one cm and drying time of nine and half hours to give a better quality end product in terms of colour and texture in thin layer drying and for ten hours at an air velocity of 12 m/s at a drying temperature of 50^0C was found to be optimum in fluidized bed drying (Balakrishnan *et al.*, 1998).

Rao *et al.* (1987) reported ECCARD (Economical Cardamom Drier) as a modified conventional curing chamber developed with better fuel efficiency, reduced duration, less cost and above all with good colour retention. He also reported the presence of a cardamom drier developed by the Indian Institute of Sciences, Bangalore with standard designs for drying 25 to 100 Kg of wet produce per day with most fuel efficiency. John (2003) reported different models of curing systems using firewood / kerosene / LPG / electricity / diesel as fuels.

Drying of cardamom using kerosene stove was attempted by Jose Ananda Bhavan of Kerala, and was evaluated by ICRI for its efficiency and economics and found handy for small quantity drying. However the availability of kerosene and risks in handling were the few limitations. Vadiraj (2004) reported that

Indian Cardamom Research Institute in collaboration with Caltex Spic India Limited initiated studies to use LPG as an alternate source of fuel for drying cardamom. The system was standardized for small quantity of 50 to 100 Kg with a drying time of 10 to 12 hours with good retention of green colour.

Varkey *et al.* (1980) depicted the design and feature of a drier developed in CFTRI, Mysore. Infrared driers were developed for cardamom drying, in which moisture removal was carried out by vacuum pump. The heating sources were thermostatically controlled and it took about eight hours for complete drying. Efficient and largely automated cardamom dryers had been designed and manufactured by several private entrepreneurs using alternate source of fuel such as kerosene, liquid petroleum gas (LPG) and diesel or using combination of fuels. In the improved driers the alternate source could be used either independently or in combination with the firewood. The entire slow curing process controlling the energy flow was fully automated. Improved systems had advantages in retaining high quality of produce with respect to colour and had substantially reduced curing duration (16 to18 hours). Cardamom dried in the improved curing chamber often fetched premium price in auctions and in retail (Spices Board, 2009).

2.5. POLISHING OF CAPSULES

Cardamom capsules had to be polished after drying. Dried cardamoms required cleaning to remove all stalks and dried remains of floral parts. This should be done best while the stuff was still hot (Pruthi, 1993). In dried cardamom polishing was generally done by rubbing against the hard surface. In recent years it could be done with the help of machine which could be operated either manually or with electric motor. Since cardamom is a high value spice crop all care should be given for efficient processing and grading (Kuruvila *et al.*, 2009).

2.6. PACKAGING AND STORAGE

Pruthi *et al.* (1962) systematically studied the packaging requirements of green cardamom and large cardamom and reported that mould growth took place at critical moisture level of 14 to 22 percentage in large cardamom (at relative humidity of 73 percentage and above) and at 16.9 to 22.8 percentage in green cardamom at the same critical relative humidity level. Shankaracharya and Natarajan (1971) reported that the factors determining preservation of the quality of cardamom during storage were moisture content together with the avoidance of physical damage and excessive heat. Cardamom cured by drier had thus to be protected from absorption of moisture, contamination with foreign odours, microorganisms or insect infestation. The specific requirement of packing cardamom included the protection of the product against sunlight in order to maintain the husk colour green or golden colour of the bleached cardamom (Zachairah and Korikanthimath, 2002). After grading, cardamoms need to be stored over a period of time, which is normally kept in double lined polythene bags.

As cardamom which keep their colour under packaging and transport were valued in the export market, the effect of exposing green dry cardamom to atmosphere of various humidity and the effect of ultra violet on them, packaged in various types of packages and stored for four months were studied at the CFTRI,Mysore. The study revealed that cardamoms at initial moisture content below 10 percentage remained well during transport and storage if packaged in 300 gauge black coloured polythene lined packages and kept in wooden chest (Viraktamath *et al.* 1965). This helped in preservation of green colour during storage and transportation. Babu *et al.* (1983) reported that polyethylene and polypropylene performed as better storage / packaging media for cardamoms.

Govindarajan *et al.* (1982) reported that cardamom dried and maintained at or below 10 per cent moisture retained the original colour and avoided mould growth. Pruthi (1985) suggested the use of wooden chests lined with tinfoil or

poly ethylene 300 gauge or craft paper coated with bitumen for bulk packaging of green cardamom with a shelf life of two to three months. For retail packaging of green cardamom, the use of 300 gauge black polyethylene lined packages stored in wooden chests lined with foil or craft paper had been recommended (shelf life four to five months). Zachairah and Korikanthimath (2002) reported that during storage some of the storage pests do impair the quality of produce. Hence there was need to evolve storage systems to minimize storage pest. If black polyethylene was used, the effect of light was further minimized and safe storage was possible for four months, required for port storage and transshipment. According to them it is advisable to make use of the dried cardamom capsules preferably within 12 to15 months of harvest, failing which the pleasant flavour and aroma are likely to be affected. The stored samples may be frequently tested for storage pests.

For long term bulk storage, polythene-lined gunny bags (strong sacks made from jute fibres) inside wooden boxes were used. The polythene bags helped to preserve the green colour of the pods. It was essential that the capsules were fully dry before they were placed in the gunny bags for storage. Any moisture within the bags would cause the capsules to rot. The stored cardamoms should be inspected regularly for signs of spoilage or moisture. If they had absorbed moisture, they should be re-dried to a moisture content of 10 percentage (Ali, 2002).

Cured cardamom had to be protected against light, air and temperature to prevent deterioration of colour and safe custody against pests and moulds since product needed to be stored for at least a few months to reach the customer (Rao *et al.*, 1987). Govindarajulu *et al.* (1993) recommended that jute sac with polyethylene bag inside or colour polyethylene between two jute bags were good for long term storage of cardamom capsules. For short duration storage a five ply multi wall paper rack with low- density polyethylene (LDPE) 200 gauge bag or gusset with high molecular high-density polyethylene (HMHDPE) liner gusset inner line coated or polypropylene woven sack with density polyethylene (LDPE)

400 gauge bag would be effective. They also suggested to store the bags in wooden box instead of open air. The storage room should be clean, dry, cool and free from pests. Mosquito netting should be fitted on the windows to prevent pests and insects from entering the room. Strong smelling foods, detergents and paints should not be stored in the same room as they would spoil the delicate aroma and flavour of the cardamom (Ali, 2002).

2.7. PHYSICAL PARAMETERS

2.7.1. BOLDNESS

The National Multi Commodity Exchange identified super bold, extrabold, and bold grades for the export market. The matured greenish capsules of diameter above 8mm and litre weight more than 450 g were classified as super bold while matured greenish capsules of diameter 7mm and above of litre weight 435 g were classified as extrabold. The bold capsules consisted of those in which 90 percentage and above have 6.5 mm and above diameter of litre weight 415 g (nmce.n.d.).

The Agmark grade specification included extrabold, bold, superior, shipment green, shipment green 2 and light for Alleppey Green cardamom and extrabold, bold, superior, Coorg Green, motta green, shipment and light for Coorg Green Cardamom (Korikanthimath, 2001).

2.7.2. BULK DENSITY

The theories used to predict the structural loads for storage structures used bulk density as a basic parameter (Nalladurai *et al.*, 2002). Balakrishnan *et al.* (2011) opined that bulk density and porosity were needed in designing near ambient drying and aeration systems, because these properties affected the resistance to air flow of the stored mass. The dried capsules should be cleaned, sorted and graded based on bulk density, colour and size (IISR.n.d.)

The Agmark had designated minium bulk density as 434 g/l for special grade of Indian whole cardamom capsules and for standard grade as 385 g/l (Agmark.n.d.). A comparative quality appraisal of exported cardamoms of India, Sri Lanka and Guatemala was reported. The Indian cardamom was found to be superior to Srilankan and Guatemalan for the physical quality parameters such as weight of 100 capsules, seed to husk ratio, bulkdensity, circumference and length. The bulk density of Indian cardamom was reported to be 384.64± 6.33 g/l while that for Guatemalan and Srilankan cardamom was 338.08 ±3.45 g/l and 286 ±7.24 g/l respectively (Kizhakkayil *et al.*, 2006)

The moisture dependant physical properties of cardamom capsules namely size, thousand capsule mass, sphericity, bulk density, true density, porosity, angle of repose, static coefficient of friction and hardness in the moisture content ranged from 8.41 to 27.87 percentage were investigated. All the physical properties except bulk density and hardness increased with increase in moisture content (Balakrishnan *et al.*, 2011). According to Gebreselassie (2012) as the moisture content of dried cardamom increased from 9.9 to 23.29 percentage, the bulk density, true density and porosity decreased from 408.2 to 358.90 kg/m^3, 926.57 to 787.19 kg/m^3 and 55.94 to 54.41 percentage respectively. The moisture dependant physical properties were important since design of unit operations for mechanical and pneumatic cleaning, transportation, processing and storage of cardamom seeds were dependent on moisture content. According to him, the relative reduction in the densities at high moisture content could be attributed to less weight gain due to the added moisture in relation to the concomitant volumetric expansion of the seeds.

2.7.3. COLOUR

Balakrishnan *et al.* (2002) was of the opinion that the green colour of the cardamom capsules was one among the important characters in considering quality cardamom with reference to its market value. The glossy green coloured external appearance of cardamom capsules was primarily due to the presence of

total chlorophyll content in the capsule skin, which was visible as green colour under white light on reflection. The correlation between instrumental colour parameters obtained with digieye and sensory evaluation of colour in orange juice had been explored. It had been demonstrated that the trained panelists could effectively evaluate orange juice hue and lightness. However small aroma differences could not be well appreciated by the trained panel (Vazquez et *al.*, 2011).

2.7.4. TEXTURE

Voisey (1971) reported that instrumental measurements were preferred over sensory evaluations for research and commercial applications because instruments reduce variation among measurements due to human factors; were more precise; and could provide a common language among researchers, companies, regulatory agencies and customers. The relevance of instrumental measurements depended on how well they predict sensory attributes. Textural properties of dehydrated products were normally measured as puncture force, which was a measure of the hardness of the product surface and was an indicator of the extent of case hardening that had occurred during drying (Kim and Toledo, 1987; Lin *et al.*, 1998).

The demand for instrumental measurements was often rationalized with a need of cheap, efficient and objective measurements (Lawless and Heymann, 1998). Several statistically significant correlations were found in literature between sensory and instrumental measurements (Meullenet *et al.*, 1997; 1998).

2.8. CHEMICAL PARAMETERS

2.8.1. MOISTURE

Maximum moisture content was set for all herbs and spices based on the maximum allowable amount of moisture for the product to remain stable. This measure of the amount of moisture is important since moisture content

determined weight and weight was used in pricing. With highly priced commodities traded on weight, one percent moisture increase in the product as shipped can result in increased weight and increased profits for the original exporter (Muggeridge, 2001).

Moisture content of commercial samples of cardamom had been found to be varying from 7 to 20 percentage depending upon the region and mode of curing (Varkey *et al.*, 1980). It was found that 10 percentage moisture was ideal for the retention of green colour which also depended on the type of drying. Well dried capsules produced a typical tinkling sound on shaking (Nair, 2011).

Varkey *et al.* (1980) had reported the initial moisture content as a range of 81-84 percentage. According to Gopalakrishnan (1986) final moisture of cardamom went up immediately according to the relative humidity of the storage room. Kannan (1995) reported the moisture content of cardamom at harvest as 75 to 80 percentage. Jose *et al.* (2001) estimated the initial moisture content to be 83 percentage. Jose (2010) reported that the moisture content would vary slightly with the maturity of capsules and cultivar. According to Nair (2011) the overall acceptability of cardamom should be determined by capsule size, colour, moisture content, physical hygiene, insect infestation, animal and other excreta, microbial load and volatile oil content.

2.8.2. CHLOROPHYLL

Arjunan (1980) reported that the retention of green colour in cardamom was much important as it fetches premium price in the export market. Kumara *et al.* (1985) studied the effect of maturity and storage on the chlorophyll content and essential oils of cardamom fruit (*Elettaria cardamomum*). According to them, with increase in maturity the parameters like the chlorophyll content and essential oils were altered. The notable changes were increased volatile oil and chlorophyll content. The main effect on volatile oil composition was an increase in 1,8 cineole content and decrease in alpha terpinyl acetate content.

According to Balakrishnan *et al.* (2002) the total chlorophyll content was observed to be higher when the cardamom was dried under intermittent spouting compared to continuous spouting. Evaluation of small cardamom accessions for moisture stress resulted in identifying genotypes Mysore, Green Gold and Malabar having better adaptation to drought condition. The chlorophyll fluorescence yield reduced significantly under moisture stress treatment compared to control (Ankegowda and Krishnamurthy, 2008).

Synthesis and degradation studies indicated that total chlorophyll content declined after about 100 days from flowering. A comparative evaluation of chlorophyll contents in dark green, medium and light green capsules had shown that the depth of green colour is directly proportional to concentration of chlorophyll content of capsules. Chlorophyll a was more than chlorophyll b in fresh as well as in cured capsules. In husk, 60 percent of total chlorphyll is present in the surface layer. In the three clone tested (viz. Thachangal, Mudigree and PV1) total chlorophyll content was more in 100 days old capsule of Thachangal (2186 ppm) followed by Mudigree (1756 ppm) and PV1 (1488 ppm) . The above studies suggested that dry matter continued to increase till capsules reached maturity while chlorophyll content started declining after 100 days from flowering. The falling chlorophyll content during post ripening period is more in Mudigree (variety Malabar) compared to variety Vazhukka and Mysore, indicating delay in picking of this clone could affect the final greenness of capsules (Anonymous, 1991).

2.8.3. ESSENTIAL OIL

Essential oils are defined as the volatile oils obtained by steam or hydro distillation containing variety of organic compounds generally belonging to the class of acrylic, iso cyclic hydro carbons, tri and sesqui terpenoids and their oxygenated derivatives. Four distinct groups of compounds associated with essential oils are terpenes related to isoprene or isopentene straight chain compounds not containing any side branches; benzene derivatives and their

analogues and miscellaneous compounds containing sulphur and nitrogen (Guenther, 1972).

Essential oil of cardamom is the source for its aroma and flavour. As early as 1908 there were reports that cardamom oil contained terpinene, sabinene, limonene, 1, 8-cineole, α- terpineol, α-terpinyl acetate, terpinen-4-yl formate acetate and terpinen-4-ol (Guenther, 1975). Dried fruit of cardamom contained steam-volatile oil, fixed (fatty) oil, pigments, proteins, cellulose, pentosans, sugars, starch, silica, calcium oxalate and minerals. The major constituent of the seed was starch (up to 50 per cent) while in the fruit husk it was crude fibre (up to 31 per cent). The constituents of the spice differed among varieties, variations in environmental conditions of growth, harvesting, drying procedures and subsequent duration as well as conditions of storage. The main factor that determined the quality of cardamom was the content and composition of volatile oil, which governed the odour and flavour. The colour of the fruit did not generally affect the intrinsic organoleptic properties. However faded fruit colour generally indicated a product stored for a longer period and possibility of deterioration in the organoleptic properties through evaporation of the volatile oil (Purseglove *et al.*, 1981).

Lewis *et al.* (1967) reported that the yield of volatile oil from the seeds of important trade varieties like Alleppey Green, Coorg Green and Sakleshpur Bleached analyzed were 10.8 percentage, 9 percentage and 8 percentage respectively. The chemical composition of cardamom differed considerably with variety, region and age of the product. The content of volatile oil in the seeds was strongly dependent on storage conditions, with an average yield from two to five percentage. The oil was described as sweet, spicy, warm, lightly camphorated and citrusy (Robert, 1986; Boiswert and Hubert, 1998).

According to Govindarajan *et al.* (1982) the relative proportions of the constituents had a direct bearing on the cardamom quality. It was well known that cineole was responsible for the camphoraceous odour while other esters and

alcohols gave the pleasant fruity odour characteristic of cardamom. Coorg cardamom was considered more camphoraceous than Alleppey Green. Mathai (1985) evaluated 18 export grades (Agmark) of Indian cardamom for their chemical and physical qualities. The grades with heavier and bigger capsules, Alleppey Green Extra Bold (AGEB) and Coorg Green Extra Bold (CGEB) were inferior in their flavour constituents to the medium grade (Alleppey Green Small, AGS). Chemical bleaching of the capsules reduced the amount of essential oil in the capsules. Vasanthakumar *et al.* (1989) reported that cardamom at the black seed stage or "karimkai" was ideal for consumption as well as for essential oil extraction. It had been reported that the volatile oil, the most functionally important constituent of cardamom varied from 6.6 to 10.6 percentage in seeds for cv. Mysore and Malabar grown in India (Krishnamurthy, 1964; Krishnamurthy *et al.*, 1967; Korikanthimath *et al.*, 1999).

According to Rao *et al.* (1925) the oil content was low in the immature capsules in the order of 4 to 5 percentage, while the husk oil was reported as 0.2 percentage, having similar properties to seed oil. Kumara *et al.* (1985) reported that even though the public perception about good quality cardamom was the greenish capsule, the appearance of the capsule had little to do with the recovery of volatile oil. Husk gave good protection and prevented the loss of oil from seeds, and the loss of oil from dehusked seeds was found to be fast. According to him, seeds started losing oil the moment husk was removed and this increased with the storage time. External appearance, size or bleached colour was not the parameters to be considered while selecting cardamom for distillation. The high-grade cardamom was not economical for distillation, since it fetched better price as whole cardamom in the trade. Lower grades, which do not fetch higher value because of defective appearance, but still good from the flavour point of view, were ideally suited for distillation.

Nambudiri *et al.* (1968) found that husk does not give more than 0.1 per cent volatile oil while the reported higher values may be due to the admixture of seeds along with the husk during sieving operation. Purseglove *et al.* (1981)

mentioned that oil obtained from green and bleached cardamom were of similar composition. Govindarajan *et al.* (1982) mentioned that the available data were not clear on this point. The chemical quality of the oil obtained from seeds and husk were evaluated by Verghese (1985) using gas liquid chromatography (GLC) and infra red radiation (IR). Though there was excellent correlation and the spectra were super imposable the organoleptic profile differed. Krishnamurthy and Sampathu (2002) concluded that distillation of oil from seeds along with husk was detrimental as it is likely to impair the flavour spectrum of the oil. The specifications of the Essential Oils Association (EOA), United States, which are generally accepted by all countries, are given in Table1.

Table1.

The Essential Oil Association (EOA) of America specification for typical cardamom oil

Definition, source	Volatile oil distilled from the seeds of *E. cardamomum* (Linn.)Maton; family Zingiberaceae, cardamom grown in South India, Ceylon, Guatemala, Indonesia, Thailand, South China
Physical and chemical constants	Appearance : colorless to very pale-yellow liquid Odour and taste: aromatic, penetrating, some what camphoraceous odour of cardamom, persistently pungent, strongly aromatic taste. Specific gravity: 0.917–0.947 at 25 °C Optical rotation: +22 °+44 ° Refractive index: 1.463–1.466 at 20 °C
Descriptive characteristics Solubility	70 percentage alcohol: in five volumes: occasional opalescence Benzyl alcohol: in all proportions Diethyl phthal : in all proportions Fixed oil : in all proportions Glycerine: insoluble Mineral oil: soluble with opalescence Propylene glycol: insoluble Stability: unstable in presence of strong alkali and strong acids. Relatively stable to weak organic acids; affected by light.
Containers and storage	Glass, aluminium or suitably lined containers, filled full; tightly closed and stored in cool place, protected from light.

(EOA, 1976)

The cardamom oil had few mono or sesquiterpenic hydrocarbons and was predominantly made up of oxygenated compounds, all of which were potential aroma compounds. While many of the identified compounds – alcohols, esters and aldehydes were commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether, 1, 8-cineole and the esters, alpha-terpinyl and linalyl acetates in the composition, made the cardamom volatiles a unique combination. The aroma differences in different sources of cardamom were attributed to the proportion of the esters and 1, 8-cineole (Lewis *et al.* 1966; Salzer 1975; Wijesekera and Jayawardena 1973; Korikanthimath *et al.*, 1997). Jyothikumar and Nanjan (1982) reported that oil content was highest in crushed capsules than uncrushed capsules. The highest oil content (7.82 percentage) was recorded in the crushed seed but uncrushed seed recorded only 4.40 percent of oil. If capsules as such were distilled without crushing, the recovery of oil (1.11 percentage) was very low, compared to crushed capsules (5.49 percentage). The crushed and uncrushed husk recorded negligible quantity of oil.

Volatile oil from cardamom *(Elettaria cardamomum* Maton var. *Minisula Barhill)* contained few hydrocarbons and large amounts of 1,8-cineole, α-cineole and α- terpinyl acetate, while that from *Elettaria cardamomum* Maton var, *Major* Thewaites (the Ceylon wild cardamom) was high in monoterpenes and very poor in the above two oxygenated compounds. The oils from the *Ammomum* species were all much higher in 1, 8-cineole, around 60 to 75 percentage, and some had relatively large amounts of camphor and borneol. Thus, a complete dominance of 1, 8-cineole, camphor or borneol among the oxygenated compounds could be identified with the camphory smell (Gopalakrishnan and Narayanan, 1991).

Hydro distillation of cardamom was not practised commercially because the distillation time was more and the release of oil was due to gelatinization of starch besides hydrolysis of the esters present in the oil (Wijesekera and Nethsingha, 1975). They also reported that another disadvantage was of resulting

mass after hydro-distillation is not easily amenable for oleoresin extraction with solvents.

Krishnamurthy and Sampathu (2002) opined that steam distillation was commonly adopted for the industrial production of oil. Powdered cardamom seeds were used for the extraction of oil. In this, pressurized steam generated in a separate chamber from which it was circulated into a still which contained water and powdered cardamom seeds. The hot steam ruptured the cell wall and released the oil. The released oil evaporated and was carried by the steam into condenser where steam cooled and essential oil floated on the surface of water was separated through the separator pipe. The collected oil was vacuum dried.

The rate of distillation and the condensate temperature were carefully regulated and it was observed that keeping the condensate warm helped in clear separation of oil from water (Nambudiri *et al.*, 1968). Baruah *et al.* (1973) confirmed that the proportion of 1, 8-cineole and α -terpinyl acetate varied with the time of distillation. Purseglove *et al.*, (1981) mentioned that the release of oil was very fast by steam distillation. In the first 15 minutes ninety percentage of oil was recovered and in thirty minutes almost hundred percentages. Usually the distillation was carried for two to three hours to recover high boiling constituents.

Babu *et al.* (1983) observed that cardamom contains three to five percentage of an aromatic volatile oil, much valued in food flavouring. Storage of the volatile oil at room temperature in glass air tight bottles showed noticeable difference of aroma and flavor in oil after three to six months period. The effect was less in oil form. The oil, at longer period of storage shows higher viscosity, odour, rancidity and high eucalyptus like smell and taste after six months. But in very low quantity of 50 mg or less, this quality got reduced. It had been reported that the safe shelf life of six months for cardamom oil could retain good aroma and flavor.

Krishnamurthy and Sampathu (2002) reported that cardamom oil before storage should be free of trace amounts of moisture, and this could be accomplished by addition of anhydrous sodium sulphate. According to them, cardamom oil could be stored in aluminium or stainless steel containers. Polyethylene terepthalate (PET) bottles, which possessed very good odour barrier properties, could also be considered. Food grade high molecular high-density polyethylene (HMHDPE) containers were also being used. The oil should be filled to the full capacity of the container and stored at 8 to 10 °C and protected from light.

Quality parameters of cardamom oil obtained by supercritical carbon dioxide extraction and stored at 0°C or at ambient temperature (28 ± 3°C) were compared with the quality of commercially steam-distilled oils at ambient temperature by Gopalakrishnan (1994). α-Pinene, sabinene and limonene were the major terpene hydrocarbons which underwent remarkable changes during storage. These hydrocarbons showed 35 to 50 percentage reduction during 90 days of storage at 0°C in CO_2 extracted oil. α-Pinene and sabinene together were reduced from 7.1 to 0.4 percentage at ambient conditions. Similarly, α-limonene was reduced from 2.3 to 0.5 percentage during the same period of storage. The above hydrocarbons were reduced from 14.4 to 6.8 percentage in the commercial oil stored at ambient conditions. Cineole contents decreased from 27.0 to 21.8 percentage in the 0°C stored samples, from 27.0 to 14.7 percentage in the ambient temperature stored samples and from 38.8 to 27.8 percentage in commercial oil. Reductions in percentage proportion of these values were 19, 45 and 28 percentage respectively. Changes also took place in the terpene alcohols but were not prominent. In the CO_2 extract stored at 0°C and in distilled oil, α-terpinyl acetate content increased during 90 days of storage. In other samples, a remarkable increase of this ester content was noted by 45 days. The two minor esters, geranyl acetate and linalyl acetate, also underwent minor changes in their contents in all of the samples during storage.

2.8.4. FLAVOUR PROFILE OF VOLATILE OIL

The first detailed analysis of cardamom oil was reported by Nigam *et al.* (1965) and the constituents were identified with the help of gas chromatography (GC) and infrared spectroscopy, using authentic reference compound and published data. The volatile oil components in cardamom were summarized by Guenther (1975).

Ikeda *et al.* (1962) reported 23.3 percentage of the cardamom oil as hydrocarbons with limonene as a major component. They had also reported the presence of methyl heptenone, linalool, linalyl acetate, β-terpineol, geraniol, nerol, neryl acetate and nerolidol. Richard *et al.* (1971) identified the compounds present in commercial samples and compared them with that of the wild Srilankan cardamom oil. In 1966 and 1967 itself different commercial samples were compared for its chemical composition (Lawrence, 1978).

In cardamom, many viewed that the essential oil had very little mono-or sesqui terpenic hydrocarbons and was dominated by oxygenated compounds, all of which were potential aroma compounds. While many of the identified compounds (alcohols, esters and aldehydes) were commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether and 1,8-cineole make the cardamom volatiles a unique composition (Lewis *et al.*, 1966; Salzer, 1975; Korikanthimath *et al.*, 1997).

The cardamom oil was described as sweet, spicy, warm, lightly camphorated and citrusy (Robert, 1986; Boiswert and Hubert, 1998). According to Korikanthimath *et al.* (1999) the volatile oil contained about 1.5 percentage α-pinene, 0.2 percentage α-pinene, 2.8 percentage sabinene, 1.6 percentage myrcene, 0.2 percentage α-phellandrene, 11.6 percentage limonene, 36.3 percentage 1,8-cineole, 0.7 percentage α-terpinene, 0.5 percentage terpinolene, 3 percentage linalool, 2.5 percentage linalyl acetate, 0.9 percentage terpinen 4-ol, 2.6 percentage α-terpineol, 31.3 percentage α-terpinyl acetate, 0.3 percentage

citronellol, 0.5 percentage nerol 0.5 percentage geraniol, 0.2 percentage methyl eugenol and 2.7 percentage *trans*-nerolidol .

Lawrence (1978) observed that the basic cardamom aroma was produced by a combination of the major components 1, 8-cineole and α-terpinyl acetate. Govindarajan *et al.* (1982) reported that the oil from var. Malabar was more camphory in aroma, due to the higher content of 1, 8- cineole. Var. Mysore, or the commercial grade, known as 'Alleppey Green', contained more α-terpinyl acetate, which contributed to the mild spicy flavor. The aroma differences in various sources of cardamom were attributed to the proportion of esters and 1, 8-cineole (Wijesekera and Jayawardena, 1973; Korikanthimath *et al.*, 1999).

Based on the physical and biochemical parameters and molecular techniques, traded or exported cardamoms from India, Sri Lanka and Guatemala had been characterized (Thomas *et al.*, 2006). Indian cardamom was found to be superior for most of the physical quality parameters and for the biochemical traits. The gas chromatographic (GC) profile of the oil of Indian cardamom indicated a high quantity of α-terpinyl acetate and 1,8- cineole, which imparted aroma and flavour to the cardamom, thus reinforcing the legendary belief of the high intrinsic quality of the Indian cardamom. Chempakam and Sindhu (2008) reported six major components of cardamom essential oil namely 1, 8- cineole, α-terpinyl acetate, linalool, linalyl acetate, α-terpineol and terpin-4-ol in order of importance. The six compounds represented almost 90 percentage of the aromatic compounds of the essential oil from cardamom and all of them were oxygenated components.

A comparison of both the solvent free microwave extraction (SFME) method and hydrodistillation (HD), indicating the difference in the yields of the two major aromatic components revealed higher 1, 8-cineole and less α- terpinyl acetate with solvent free microwave extraction (SFME) and less 1, 8-cineole and more α- terpinyl acetate in hydro distillation. Hydrodistillation (HD) was characterized by a long extraction time (6 h) and high humidity level (< 99

percentage). Overall, the 1, 8-cineole fractions seemed to decrease with time, power and moisture, whereas α-terpinyl acetate seemed to increase. Monoterpene hydrocarbons are less valuable than oxygenated compounds in terms of their contribution to the fragrance of the essential oil. In the case of solvent free microwave extraction (SFME), substantially higher amounts of oxygenated compounds were seen, as compared with hydro distillation. This was probably due to the diminution of thermal and hydrolytic effects during solvent free microwave extraction (SFME). The more polar the compounds, the more readily microwave irradiation was absorbed, with better interaction between wave and matter, resulting in higher aromatic components. This corresponded with the higher levels of 1, 8-cineole, which was more polar than α-terpinyl acetate (Lucchesi *et al.*, 2007).

Quality parameters of cardamom oil obtained by supercritical carbon dioxide extraction and stored at 0°C or at ambient temperature (28 ± 3°C) were compared with the quality of commercially steam-distilled oils at ambient temperature (Gopalakrishnan, 1994). α-Pinene, sabinene and limonene were the major terpene hydrocarbons which underwent remarkable changes during storage. These hydrocarbons showed 35 to 50 percentage reduction during 90 days of storage at 0^0C in CO_2 extracted oil. α-Pinene and sabinene together were reduced from 7.1 to 0.4 percentage at ambient conditions. Similarily α-limonene was reduced from 2.3 to 0.5 percentage during the same period of storage. The above hydrocarbons were reduced from 14.4 to 6.8 percentage in the commercial oil stored at ambient conditions. Cineole contents decreased from 27 to 21.8 percentage in the 0^0C stored samples from 27 to 14.7 percentage in the ambient temperature stored samples and from 38.8 to 27.8 percentage in commercial oil. Reduction in percentage of these values was respectively 19, 45 and 28 percentage. Changes also took place in the terpene alcohols but were not prominent. In the CO_2 extract stored at 0^0C and in the distilled oil, α –terpinyl acetate content increased during 90 days of storage. In the other samples, a remarkable increase of this ester content was noted by 45 days. The two minor

esters, geranyl acetate and linalyl acetate also underwent minor changes in their contents in all of the samples during storage (Chempakam and Sindhu, 2008).

Govindarajan *et al.* (1982) had elaborated the change of concentration of major flavour constituents, their flavour description and their effect on flavour use. TLC (thin layer chromatography), column chromatography and subsequently GC (Gas Chromatography) were employed for the separation of oil constituents. Fractional distillation, infrared spectroscopy, mass spectrum and nuclear magnetic spectrum (NMR) were adopted to identify the specific compounds. The major constituents identified were alpha pinene, alpha thujene, beta pinene, myrcene, alpha terpinene, gamma terpinene and p-cymene. These were identified in the monoterpene hydrocarbon fraction of cardamom oil. Earlier gas chromatograms showed up to 31 to 33 peaks and up to 23 compounds were identified, while the improved procedure gave higher resolution with more than 150 peaks. All peaks have not been identified. Many workers used techniques like combination of fractional distillation, column and gas chromatography, mass spectrometry (MS), infra red (IR) spectroscopy and nuclear magnetic spectrum (NMR) to identify the constituents of cardamom oil (Zachariah, 2002).

Menon *et al.* (1999) studied the volatiles of freshly harvested cardamom by adsorption on Amberlite XAD-2, from which the free volatiles were removed by elution with pentane: ether and glycosidically-bound volatiles with methanol. Gas chromatographic–mass spectrometric analysis of the two fractions led to the identification of about 100 compounds. Among the free volatiles the important ones were 1, 8-cineole, and alpha terpinyl acetate. The less important ones were geraniol, alpha -terpineol, *p*-menth-8-en-2-ol, γ-terpinene, β-pinene, carvone oxide etc, while a large number of compounds were present in trace amounts. Among the aglycones the important ones were 3-methylpentan-2-ol, α-terpineol, isosafrole, β-nerolidol, *trans*,*trans*-farnesol, *trans*,*cis*farnesol, *cis*,*trans*-farnesol, T-murrolol, cubenol, 10-epi-cubenol, *cis*-linalol oxide, tetrahydrolinalol etc. Sixty-eight compounds were identified in the volatile fraction while sixty-one compounds were identified in the glycosidically bound fraction. Cardamom oil

analyses were found to be richer in oxygenated compounds all of which were potential aroma compounds.

Govindarajan *et al.* (1982) had described the ratio of esters to 1, 8- cineole in different commercial types of cardamom oil. In occasional samples, defective note described as slightly 'oxidised terpinic' were noted at high dilution levels, but were over shadowed by total cardamom aroma at higher level of concentrations. Samples markedly camphory (lacking sweet aromatic components) or high in defectiveness oxidized terpinic, resinous, oily, earthy or bitter in flavour were rated poor unacceptable. He suggested that quality grading of cardamom was possible by observing three major attributes of balance of profile, intensity/tenacity and absence of defects.

According to many workers the ratio of 1, 8-cineole to alpha terpinyl acetate was a fairly good index of the purity and authenticity of cardamom volatile oil (Purseglove *et al.*, 1981). The ratio was around 0.7-1.4. Cardamom Research Centre, Appangala (Karnataka) under the Indian Institute of Spices Research (IISR), Calicut (Kerala) collected many accessions from cardamom growing areas with the flavor ratio more than one. 1, 8-Cineole and α–terpinyl acetate together with terpene alcholos (linalool, terpinen-4-ol and α–terpineol) were important for the evaluation of aroma or quality of cardamom (Zachariah, 2002).

Pillai *et al.* (1984) made study of the 1, 8-cineole and α–terpinyl acetate contents of the cardamom oil derived from diverse source and indicated that Guatemalan cardamom oil was marginally superior to Indian cardamom oil due to the higher content of alpha terpinyl acetate. They also reported that the high concentration of 1, 8- cineole made the oil from Papua New Guinea poor. The works of Gopalakrishnan and Narayanan (1991) reported that the extraction methods like cryogenic grinding and supercritical extraction influenced the flavor profile. Such extraction techniques extracted the trace compounds that were otherwise lost in other methods of extraction.

Raghavan *et al.* (1991) have standardized a method for the separation of 1, 8-cineole from cardamom oil by adduct-formation using ortho-phosphoric acid. In this method 100 ml of cardamom oil was first treated with 30 ml of ortho-phosphoric acid and then with 50 ml of petroleum ether with constant stirring. The adduct (precipitate) formed was filtered. The precipitate was air dried and extracted with 500 ml of hot water. Cineole fraction was released as a separate layer and recovered. The aqueous layer was extracted with 200 ml of petroleum ether and desolventized to get terpinyl acetate rich fraction. The gas chromatographic analysis of these fractions showed that cineole fraction (28 ml) contained 80 per cent cineole and 18 per cent terpinyl acetate while the terpinyl acetate fraction (58 ml) contained 76 per cent terpinyl acetate and 16 percent cineole.

An attempt was made to produce terpeneless cardamom oil by column chromatography technique using activated silica gel (Raghavan *et al.*, 1991). Petroleum ether was used to elute out terpene fractions and acetone was used to elute oxygenated compounds. It was concluded that overall flavour value of the deterpenated oil was not better than the original non-deterpenated oil. The finer notes of the original oil were missing in the deterpenated oils.

2.8.5. Residue of sodium, potassium, magnesium, ascorbic acid, citric acid, naphthalene acetic acid, polyethylene glycol and copper in the treated cardamom capsules

The nutritional composition of cardamom (per 100g) and the recommended dietary allowances had been put forward by United States Department of Agriculture (USDA). The table presented below.

Table 2 .The nutritional composition of cardamom (per 100g)

Cardamom Nutritional Value per 100 g

Principle	**Nutrient Value**	**Percentage of RDA**
Energy	311 K cal	15.5%
Carbohydrates	68.47 g	52.5 %
Protein	10.76 g	19 %
Total Fat	6.7 g	23 %
Cholesterol	0 mg	0 %
Dietary Fiber	28 g	70 %
Vitamins		
Niacin	1.102mg	7 %
Pyridoxine	0.230 mg	18 %
Riboflavin	0.182 mg	14 %
Thiamin	0.198 mg	16.5 %
Vitamin A	0 IU	0 %
Vitamin C	21mg	35 %
Electrolytes		
Sodium	18 mg	1 %
Potassium	1119 mg	24 %
Minerals		
Calcium	383 mg	38 %
Copper	0.383 mg	42.5 %
Iron	13.97 mg	125 %
Magnesium	229 mg	57 %
Manganese	28 mg	1217 %
Phosphorus	178 mg	25 %
Zinc	7.47 mg	68 %

(Source: USDA National Nutrient data base)

(Leonard *et al*, 2001)

According to Muthuswamy *et al.* (2012) until 1990 India used to export nearly 80 percentage of its total production of cardamom to particularly North America and Europe. Because of strict food commodity standards and stringent specifications, the country was able to expert even 10 percentage of our past achievement. They attributed such down trend to the presence of higher contents of heavy metals and pesticides in the cured cardamom. Heavy metals uptake

resulting from application of fertilizers in soil and foliar region were found to be very high. The effect of heavy metals and nutrient uptake by soils in cardamom hill reserves studied by the above researchers revealed highest concentration of potassium in cardamom capsule rind (43487 ppm) followed by whole capsules (17778 ppm) and seed (10539 ppm). The concentration values for phosphorous, magnesium and sulphur in seeds were 1884.9, 1567.2 and 1008.4ppm respectively. They also observed heavy metal accumulation in capsules and leaves with 6.2 ppm for copper.

The DASH diet, a dietary recommendation limits total fat, saturated fat and cholesterol and provides plenty of fiber, potassium, calcium and magnesium in food. The DASH diet limits sodium to between 1500 mg and 230mg/day (Mayoclinic. n.d.).

No maximum residue limits (MRLs) for napththalene acetic acid , its salts, ester and acetamide had been established in the Codex Alimentarius, the food code established by the United Nations's World Health Organization and the Food and Agricultural Organization; therefore issues of compatability between Codex MRLs and United States tolerances do not exist. Moreover, no Canadian or Mexican MRLS had been established for naphthalene acetates (Anonymous, 2007).

The Environmental Protection Agency (EPA) had reviewed all toxicity studies submitted and had determined that the toxicity database was essentially complete to support a registration eligibility determination for all currently registered uses of the naphthalene acetates. The naphthalene acetates showed low acute toxicity, were not mutagenic and were not expected to be carcinogenic. The most common effect (acute/short-term) from high exposure to the naphthalene acetate was reduced body weight gain. Chronic effects included vomiting, stomach/eosins and slightly sinusoidal histiocytosis in the livers of males. Environmental Protection Agency (EPA) had not identified any metabolities (break down substances) of toxicological concern (Anonymous, 2009a).

Several tolerance expressions for naphthalene acetates resulting from applications of napththalene acetic acid (NAA), its salts, ester and acetamide were reported. Currently the tolerances listed under 40 CFR and 180. 155 (a) are for residues of 1-naphthalene acetic acid. The tolerances listed under 40 CFR & 180. 155 (b) are for residues of the ethyl ester of 1-naphthalene acetic acid. The tolerances listed under 40 CFR and 180. 309 are for residues of alpha-naphthalene acetamide and its metabolite alpha naphthalene acetic acid. According to 40 CFR and 180.3(d) (7), for commodities having both napththalene acetic acid (NAA) and napththalene acetic acid (NAA) metabolite tolerances, the total amount of residues, calculated as napththalene acetic acid (NAA), shall not exceed the higher of the two tolerances (Anonymous, 2009a).

The United States Environmental Protection Agency had recommended the present tolerance limit for naphthalene acetate as 1ppm for apple, pear, quince and 0.1 ppm for sweet cherry, olive, sweet orange and 0.5 ppm for pineapple. They had recommended for a review to reassign the tolerance limit to 0.1ppm for apple, sweet cherry, sweet orange, pear and quince and 0.7ppm for olive (Anonymous, 2007).

Polyethylene glycol refers to an oligomer/polymer of ethylene oxide. Polyethylene glycol (PEG) is prepared by polymerisation of ethylene oxide and is commercially available over a wide range of molecular weights. Polyethylene glycol (PEG) finds a number of uses. It is used as an antioxidant agent in food, used in a number of tooth pastes, skin cream etc (Anonymous, 2009a).

Ethylene oxide is used in the production of several authorized food additive and may be present as an impurity in low amounts in the final product. Ethylene oxide purity criteria had been set for polyethylene glycol 6000, Commission Directive 2000/ 63/ EC, as $\leq$ 1mg/kg. The committee had now informed that the currently achievable detection limit for ethylene oxide is well below the specified purity criteria of 0.5 and 1mg/kg. For example, the used and reported detection limit for ethylene oxide in entero hemorrhagic Escherichia coli

(EHEC) is according to the petition, 0.2 mg ethylene oxide per kg cellulose (OFCA, 1996). The same limit has been used in the screening of spices for their ethylene oxide content (Fowles et *al.*, 2001).

Polyethylene glycols having a molecule weight of 400, 1540 & 4000 caused no adverse effect upon dogs when fed in their diet for one year at a level of 2 percentage. When fed to rats for 2 year as part of diet, polyethylene glycols 1540 and 4000 had no effect at a level of 4 percentage and polyethylene glycol 400 had no effect at a level of 2 percentage (Palty, 1963).

The committee for veterinary medicinal products reported that dosages of 60 mg/kg BW/day of PEG 1500 or of 20mg/kg b.w/day of PEG 4000 did not cause any significant adverse effects (mortality, frequency of infection, lifespan, fluid consumption, body weight gain, kidney and liver weights, frequency of size of litters, blood cytology, urinary albumin and sugars, occurrence of neoplasm and micropathology) in albino rats when administered in the drinking water over a two-year period (Anonymous,2009a).

In another review, four groups received PEG 1500 view drinking water at doses approximately equal to 15, 590, 2700 and 16900mg/kg/ BW/day. Four other groups received PEG 4000 at doses of 0. 85, 3.6, 17 and 620 mg/kg body weight/day. The percentage of deaths at the end of the 2 years period was within normal limits (55 percentage). No significant clinical symptoms or (histo-) pathology lesions were found. Neoplasms and degenerative changes in the kidneys were reported, but these were distributed equally in treated and untreated animals (Anonymous, 2009a). The committee concluded that maximum residue units for tissues are not necessary to ensure consumer safety and recommended the inclusion of polyethylene glycols in Annex II of Council Regulation (EEC) No. 2377/90 (Anonymous, 2009a).

The guideline on the specification limits for residues of metal catalysts was specified in drug substances and excipients by European Medicines Agency.

Copper is the functional component in a variety of cuproenzymes (eg. Cytochromé oxidase, ascorbic acid oxidase and superoxide dismutase). It plays an important biological role in redox reaction and in scavenging of radicals. United States Recommended Dietary Allowance (USRDA) for dietary intake recommends 0.9mg/day in adult men and women aged more than ninety years. The joint expert Committee on Food Additives has recommended a PMTDI (Provisional Maximum Tolerable Daily Intake) of 0.5mg / kg /day. The United Kingdom, Department of Health, 1991 proposed a dietary reference value of 1.2 mg/day for adults aged 18 years and over (Anonymous, 2007).

Copper is subject to a number of homeostatic mechanisms invivo following oral ingestion that reduces the likely hood of toxic sequelae if intake exceeds the normal requirements. The mechanism involved include binding to metallothionein, absence of significant storage, binding to albumin and transcuprcin and biliary excretion (Anonymous, 2007).

According to WHO, drinking water quality guideline is 2mg/L for copper based on a NOEL (No Observed Effect Level) of 5mg/kg/day in dogs. In United Kingdom, the safe upper level for total daily intake is 10 mg/day; at least 1mg/day for non dietary intake. Although all metals have inherent toxic properties some elements such as iron, zinc, chromium, manganese, copper and molybdenum are important in human nutrition. Competition for absorption sites, nutritional status and other factors can lead to interactions amongst the metal elements, particularily molybdenum, zinc, iron and copper. However this is unlikely to be a major issue in the case of metal catalyst residue given their anticipated minor contribution to metal intakes (IOSTA, 2008).

Heavy metals are chemicals that are known to be toxic to human and are often impossible for the human body to metabolise. Therefore their presence need to be controlled and should not exceed the Codex maximum residue limits, to prevent a build up in the body over a period of time. Typical heavy metals found in spices are lead, cadmium, zinc, tin, arsenic and copper (IOSTA, 2008). The

evaluation of heavy metal contents in spices and herbs available in the polish market were studied and the results reported an excessive amount of lead (40 percentage of basil, 42 percentage of cinnamon, 25 percentage of savory and 6 percentage of dried onion samples). Zinc and Copper levels in all herbs and spices were within safe limits while increased levels of Cadmium were defected in 20 percentage of basil, 25 percentage of savory and 42 percentage of cinnamon samples (Krejpcio *et al.*, 2007).

2.9. SENSORY QUALITY EVALUATION

Many researchers like Ilveen and Armstrong, 1996; Piggott *et al.* (1998) observed the sensory analysis as a scientific discipline in which man was a measure instrument. They defined it as "a discipline used to evoke, measure, analyze and interpret reactions to the characteristics of foods and similar materials as they were perceived by the sense of sight, smell, taste, touch and hearing". The discipline of sensory analysis used scientific principles drawn back from food science, physiology, psychology and statistics (Piggott *et al.*, 1998). Costell (2002) stated that the sensory quality was much difficult because it depended not only of food characteristics but of the consumer. Thus sensory quality could be product oriented or consumer oriented. Therefore, the role of sensory analysis in the food industry could be more important than it was actually.

Sensory control was recommended only in critical steps while physical and chemical analyses were realized at different stages (Munoz, 2002). Sensory analysis had different approaches, requirements and practical applicability and usually required a lot of time, difficulties in analyzing data and the expertise were not always available, difficult to organize a trained panel test, to have the adequate reference standards and difficulties to focus the objective for the analysis so to perform the optimum sensorial test (Aumatell, 2009). The sensory analysis regarded by food scientists as the touch stone of quality was highly sensitive to concentrations ranging from 10^{-8} to 10^{-4} ppm. The superiority of the

variety Alleppey Green could be attributed to its superior sensory qualities (Nair, 2011).

Appearance

Almedia and Noguira (1995) reported that organoleptic properties determine acceptance of food by the consumer with appearance being the first factor that determines the acceptance or rejection of a food.

The quality of a food item might simply be judged from its appearance when it was placed in front of a consumer. Sivasankar (2002) reported that physical factors such as size, shape and freedom from defect/damaged surface, type and extent of damaged parts and optical properties such as colour, gloss and transparency and the consistency of the product in different batches/packages were also appearance factors that was indicative of quality. According to Srilakshmi (2010) surface characteristics of food products contributed to the appearance. Interior appearance could also be evaluated. Sight plays a role in the assessment of the lightness of foods.

Colour

Jellinick (1986) reported that the first impression of the food is usually visual band major part of our willingness to accept a food, depend upon its colour. Dorko and Penfield (1993) reported that the aesthetic, safety, sensory characteristics and acceptability of food are all affected by colour.

According to Maskan (2001) colour was one of the most important appearance characteristic because it affected directly consumer preference for the food material. The colour observed by human beings was the perception of the wavelengths coming from the surface of the object on the retina of the eyes (Tijskens *et al.*, 2001).

According to Purseglove *et al.* (1981) the colour of the cardamom fruit did not generally affect the intrinsic organoleptic properties. However faded fruit

colour generally indicated a product stored for longer period and the possibility of deterioration in the organoleptic properties through the evaporation of volatile oil. When light striked on object, it is reflected, absorbed or transmitted, but it is the reflected light which determined the colour of a material. Therefore, the appearance could change depending on the amount of light, the light source, the observer's angle of view, size and background differences (Giese, 2000). The impact of the selected herbs and spices on sensory and microbial properties of heat treated milk beverage was studied by Kumarasiri *et al.* (2012). According to the sensory data for the cardamom and iramusu incorporated beverages, appearance, colour, odour, taste, texture/mouthfeel and overall acceptability of two beverages were satisfactory and the mean scores for all the attributes were higher than the category of ' like slightly' in nine point hedonic scale indicating good overall acceptability of products.

Balakrishnan *et al.* (2002) were of the opinion that the green colour of the cardamom capsules as one among the important characters in considering quality cardamom with reference to its market value. The glossy green coloured external appearance of cardamom capsules was primarily due to the presence of total chlorophyll content in the capsule skin, which was visible as green colour under white light on reflection.

Texture

Szczesniak (1963) proposed texture profile as a systematic approach to sensory texture analysis based on mechanical, geometrical, and other characteristics. Mechanical characteristics included five basic parameters like hardness, cohesiveness, viscosity, elasticity, and adhesiveness and geometrical and secondary parameters like brittleness or fracturability, chewiness, and gumminess. Geometrical characteristics included those related to shape and orientation of particles. The other characteristics comprised moisture and fat content and included qualities such as moist, oily and greasy. Sherman (1969) proposed some modification to the Szczesniak system. deMan (1999) considered

texture as an important aspect of food quality, sometimes even more important than flavour and colour. Sensory panel responses associated with masticatory tertiary characteristics of the Sherman texture profile for solid, semisolid and liquid had been proposed.

Katz and Labuza (1981) examined the relationship between water activity (aw) and crispness in a study of popcorn and found a direct relationship between crispness and water activity. It had been reported that at lowest values of water activity most products were hard and crisp (Bourne, 1987). de Man (1999) opined water activity (aw) and water content had profound influence on textural properties of foods.

The polysaccharides that make up the plant cell wall (cellulose, hemicelluloses and pectin) form the basis of structural hierarchy. Changes in texture during ripening, processing and storage are mainly related to (bio-) chemical conversions of pectin. Pectin principally abundant in the plant middle lamella plays a crucial role in cell-cell adhesion and moreover is brought into solution more easily and is more chemically reactive than the other cell wall polymers (VanBuren, 1979). Sensory evaluation of crispness and sounds recorded when crushing food samples (eg. biscuits wafers and potato chips manipulated by humidity) were found to correlate significantly with each other (Mohamed *et al.*, 1982; Seymour and Hamann, 1988). Texture is a characteristic at the plant organ level, depending on a structural hierarchy (Waldron *et al.*, 2003).

Xiao *et al.* (2009) studied the effect of different pre treatments on drying kinetics and quality of sweet potato bars in terms of textural properties, micro structure and colour undergoing an impingement drying. It was found that the dried sweet potato bars subjected to hot water blanching and superheated steam blanching pre treatments had a homogenous compact structure. In addition, no pores and starch granules were found on the surface of the samples. As a result the structure would slower water transfer or penetration during drying or

rehydration process. However the samples subjected to citric acid, pre-treated for 30 minutes had large with non uniform pores and lots of starch granules on its surface which facilitated rapid water migration during drying. Different pre treatments caused various changes of microstructure of the samples and lead to varied product properties.

Taste

It is generally agreed that there are only four basic or true tastes: sweet, bitter, sour and salty. According to Teranishi *et al.*(1971) perception of the basic taste qualities resulted from a pattern of nerve activity coming from many taste cells specific receptors for sweet, sour, bitter and salty do not exist.

Sharma *et al* (1995) revealed that the taste is primary and most important quality among various attributes. They also reported that colour scores were significantly related with acceptability. It may be envisioned that a single taste cell possessed multiple receptor sites, each of which might have specifity.Taste sensation which the taste buds register were categorized as sweet, salt, sour or bitter as reported by Srilakshmi (2010). Study conducted on changes of nutritional and organoleptic quality of flavoured aonla candy. On the basis of organoleptic evaluation and biochemical characters it was concluded that the candy prepared from cultivar Krishna and flavoured with cardamom powder was found to be best aonla candy (Nayak *et al.*, 2012).

Flavor

Flavour has been defined by Hall (1968) as follows: "Flavour is the sensation produced by a material taken in mouth, perceived principally by the senses of taste and smell, and also by the general pain, tactile and temperature receptors in the mouth. Flavour also denotes the sum of the characteristics of the material which produce that sensation". Flavour is a property of material (a food as well as of the receptor mechanism of the person ingesting the food. Although flavour is composed mainly of taste and odour, other qualities contribute to the

overall sensation. de Man (1999) reported that texture had a very definite effect. Smoothness, roughness, granularity and viscosity could all influence flavour, as could hotness of spices, coolness of menthol, brothiness or fullness of certain aminoacids and tastes described as metallic and alkaline.

According to Sivasankar (2002) evaluation of flavour factor was highly subjective and depended on discriminating ability of the consumer as flavour included the sense of smell as well as the sense of taste experienced by the consumer. People differed in their sensitivity to different odours and tastes as much as in their preference for various types of foods. In addition, consumers were influenced to some extent on the appearance, colour and texture of the food while evaluating the flavour characteristics. The flavour of food has 3 components – odour, taste and a composite of sensations known as mouth feel (Srilakshmi, 2010).

Odour

Burfield (2002) put odour profile as a written description of the olfactory sensations evoked during the smelling of an essential oil or other natural raw material. Perfumers assessed the odour profile by dipping the essential oil/absolute/resinoid etc. onto a perfumers' strip in order to appraise top, middle and bottom notes. A "smelling strip" was made of carefully selected paper which has a certain degree of absorbency which enables a smooth evaporation profile of all contained individual components.

Srilakshmi (2010) reported that a substance which produces odour must be volatile and the molecules of the substances must come in contact with receptors in the epithelium of the olfactory organ. She also stated that aroma was able to penetrate even beyond the visual range when comparatively volatile compounds were abundant. The detection threshold of cardamom aroma determined in different media viz., water, sugar solution and milk recorded that cardamom aroma could be better perceived in water and sugar solution than in milk (Senthil and Bhatt, 2011).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Effect of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardamomum* (L.) Maton)" was undertaken at the Department of Processing Technology, College of Agriculture, Vellayani during the period 2010-2012. The experiment was done with the objective of standardizing pretreatment of cardamom capsules under different curing methods and also to study the influence of pretreatment and curing methods on quality parameters of cardamom. The details of experimental site, season, weather conditions, materials used and the methods adopted for pre treatments, different curing methods tried and the quality parameters analyzed under different pre treatments in different curing methods are presented in this chapter.

3.1 Experimental site

3.1.2 Location

The matured capsules of small cardamom (*Elettaria cardamomum* (L.) Maton) of variety Njallani cultivated at the Cardamom Research Station, Pampadumpara situated at 9^0 45' N latitude and $77^0$10'E longitude at an altitude of 1100 M above mean sea level was used for the study. The pre treatments and curing were carried out at Cardamom Research Station, Pampadumpara and the quality characters of cured cardamom were analyzed at Department of Processing Technology, College of Agriculture, Vellayani, Central Tuber Crops Research Station, Sreekariyam and Cashew Export Promotion Council Laboratory, Kollam.

3.2 Season

The matured fresh capsules of cardamom harvested from August to October 2011 were used for the study.

3.3 Weather

Pampadumpara experiences a humid tropical climate. The mean annual rainfall for the year 2010 was 2012.9 mm followed by 2057 mm for 2011. The mean annual maximum temperature of 32^0C and mean annual minimum temperature of 12^0C was recorded for the year 2010 and 2011 respectively. The maximum mean annual relative humidity for the year 2010 was 95.13 percent followed by 94.79 percent for 2011 and the minimum mean annual relative humidity for the year 2010 was 67.92 percent followed by 67.13 percent for 2011.

3.4. Harvesting and collection of cardamom capsules

The fresh harvested capsules were washed to remove soil and filth and were allowed to drain.

3.5. Pre treatment of capsules

The drained capsules were subjected to pre treatments by dipping in different chemicals with the objective of retaining parrot green color of harvested capsules since such a product fetches premium price in the market. The present recommendation involves soaking fruits in two percentage washing soda (Na_2CO_3) for 10 minutes prior to drying, which is said to have a profound influence on fixing green color during subsequent drying and storage as reported by Natarajan *et al.*(1968).

Concentration of pre treatment chemicals was fixed by conducting a preliminary trial. Capsules were immersed in the following chemicals at specified concentration for 10 minutes and subjected to both conventional curing and modern curing.

1. Sodium carbonate - 2%
2. Potassium carbonate - 2%
3. Magnesium sulphate - 1%

4. Sodium sulphate - 1%
5. Calcium sulphate - 1%
6. Ascorbic acid - 0.1%
7. Citric acid - 0.1%
8. Polyethylene Glycol - 0.1%
9. Naphthalene Acetic Acid - 500ppm
10. Control - No treatment

Based on the colour and appearance of the pre treated capsule, the treatments were modified as follows by inclusion and deletion of some treatments.

(1) Sodium sulphate and calcium sulphate should be removed from the experiment because capsules treated with these chemicals showed high bleaching effect.

(2) The concentration of sodium carbonate and potassium carbonate may be reduced from two percent to one percent in the following experiment.

(3) Three other chemicals should also be included.
   (1) Sodium hydroxide 1%
   (2) Sodium bicarbonate 1%
   (3) Copper acetate 1%

(4) Time of dipping for all the treatments should be reduced to two minutes, since soaking the capsules for 10 minutes in these chemicals were found to bleach and split the capsules on curing.

Hence the following treatments were finalized for the pre treatment with the specified concentration for two minutes.

Treatments

Sodium carbonate - 1%

Potassium carbonate - 1%

Magnesium sulphate - 1%

Sodium hydroxide - 1%

Sodium bicarbonate - 1%

Ascorbic acid - 0.1%

Citric acid - 0.1%

Polyethylene Glycol - 0.1%

Naphthalene Acetic Acid - 500ppm

Copper acetate - 1%

Control - No treatment

3.6. Curing of Cardamom capsules

Cardamom curing can be defined as the process in which the moisture content of freshly harvested cardamom is reduced from 80% to 12% at an optimum temperature of 45-55^{0}C to retain green colour and volatile oil to maximum extent (Vadiraj, 2004).

The pre treated capsules were subjected to the following two types of curing.

1. Conventional curing
2. Modern curing

Treatments

T1 - Sodium carbonate 1% + Conventional curing

T2 - Sodium carbonate 1% + Modern curing

T3 - Potassium carbonate 1% + Conventional curing

T4 - Potassium carbonate 1% + Modern curing

T5 - Magnesium sulphate 1% + Conventional curing

T6 - Magnesium sulphate 1% + Modern curing

T7 - Sodium hydroxide 1% + Conventional curing

T8 - Sodium hydroxide 1% + Modern curing

T9 - Sodium bicarbonate 1% + Conventional Curing

T10 - Sodium bicarbonate 1% + Modern curing

T11 - Ascorbic acid 0.1% + Conventional curing

T12 - Ascorbic acid 0.1% + Modern curing

T13 - Citric acid 0.1% + Conventional curing

T14 - Citric acid 0.1% + Modern curing

T15 - Polyethylene glycol 0.1% + Conventional curing

T16 - Polyethylene glycol 0.1% + Modern curing

T17 - Naphthalene Acetic Acid 500 ppm + Conventional curing

T18 - Naphthalene Acetic Acid 500 ppm+ Modern curing

T19 - Copper acetate 1% + Conventional curing

T20 - Copper acetate 1% + Modern curing

T21 - Control in Conventional curing

T22 - Control in Modern curing

Lay out of experiment

Design : Completely Randomized Design (CRD)

Treatment : 22

Replication : 3

3.6.1. Conventional curing

Conventional curing was undertaken at the Cardamom Research Station, Pampadumpara. The pre treated capsules were dried in curing chamber under controlled temperature for 36 hours to retain delicate flavour and green color. Heat required for drying was produced by burning firewood in iron kiln and heat was passed through pipes made of galvanized iron sheet. Drying temperature was

maintained at 50^{0}C for the first four hours and subsequently reduced to 45^{0}C by opening the ventilators and using exhaust fan and raised to 60^{0}C for one hour.

3.6.2. Modern curing

Modern curing was undertaken at a private firm at Amayar in Idukki district using modern drier for 11 hours. Heat was generated by burning firewood and passed to the drying chamber where the capsules tied in polythene nets were kept. The initial drying temperature was 45-50^{0}C finally raised to 60^{0}C which was controlled electrically.

3.7. Polishing

Pre treated, cured hot capsules were immediately subjected to polishing in the polisher to remove all stalks and dried remains of floral parts.

3.8. Packaging and storage

Pre treated, cured and polished capsules were packed in low density polyethylene covers and stored under ambient conditions kept at Department of Processing Technology, College of Agriculture, Vellayani for conducting further physical, chemical and sensory analysis.

3.9. Observations

3.9.1. Physical parameters

Physical quality parameters like boldness, bulk density, colour and texture of treated capsules were recorded.

3.9.1.1. Boldness

Boldness was measured by passing entire quantity of pre-treated capsules through sieves of different mesh sizes viz; eight, seven, six mm and five mm by allowing five percentage droppings by count (Anonymous, 2011).

3.9.1.2. Bulk density

Bulk density of treated cardamom capsules was determined as per American Spice Trade Association (ASTA) method (Pruthi, 1999) and expressed in g/l.

Test sample was filled in a 50 ml cylindrical container, shook horizontally thrice and filled again as much as possible to the brim. The measure was tapped on a level and hard surface three times by changing the position each time and filled again as much as possible to little over the brim. By moving a thin strip of straight metal sheet of about 10 mm width and 150 mm length in level with the top of the measure, the excess material was removed. The contents were weighed in a balance (Pruthi 1999).

$$\text{Bulk density } (P_b) = \frac{\text{Mass of the capsule filled in cylinder (M)}}{\text{Volume of cylinder (V)}}$$

Bulk density was expressed in gram per litre.

3.9.1.3. Colour.

The colour (ΔE) of treated and untreated cardamom was measured using spectrophotometer CM2600D (Konica Minotta, Inc, Osaka,Japan) (Plate 1). Samples filled in a petridish of 5cm diameter and 15 mm height were exposed to the spectrophotometer and the colour co-ordinates (L*, a* and b*) were measured according to CIE (Commission International d Enluminure).

L* - Lightness/Darkness of sample with values varying from 0 (black) to 100 (white).

a* - greenness/redness of sample with values ranging from -60 (green) to + 60 (red).

b* - blueness/yellowness with values ranging from -60 (blue) to +60(yellow).

Plate 1. Instrumental measurement of colour of small cardamom using Spectrophotometer

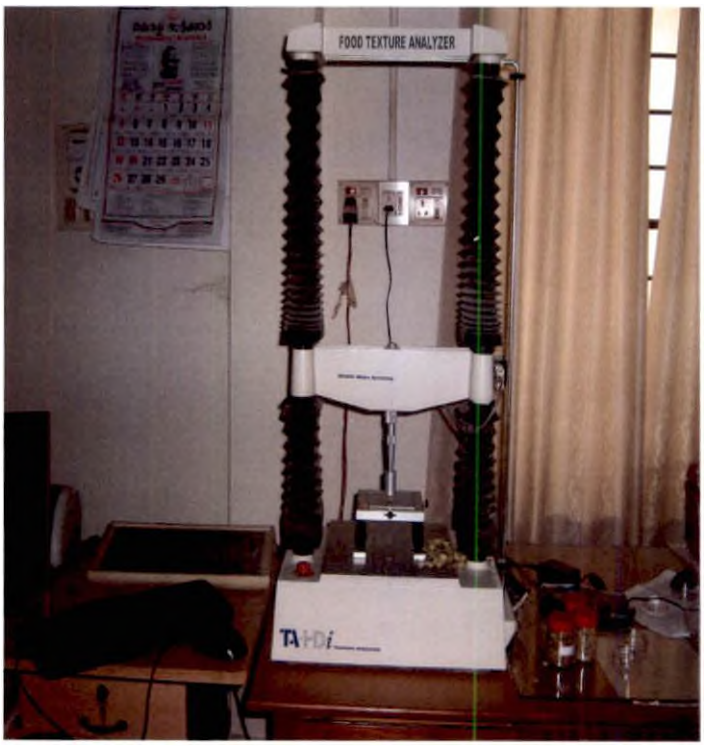

Plate 2. Food Texture Analyzer

From these primary colour values, the total colour difference was calculated using the following equation (Tijskens *et al.*, 2001; Zhang *et al.*, 2007)

$$\Delta E = \sqrt{(L_0-L)^2 + (a_0 - a)^2 + (b_0 - b)^2}$$

Where L_0, a_0 and b_0 represents the co-ordinates of standards.

$L_0 = 99.34$, $a_0 = -0.03$,

$b_0 = -0.1$

While a* value represent the greenness/redness of the sample and since green colour in cardamom is an important parameter in consumer market and hence a* values was also statistically analyzed apart from total colour difference (ΔE) values.

3.9.1.4. Texture (Firmness)

Texture of the cardamom capsules was measured using a food texture analyzer (TAHDi-Stable Microsystems, United Kingdom) (Plate 2 and 3) by snap test method. Sample was placed on a heavy duty platform with a crisp support rig in the centre. When lowered, the spherical stainless steel ball probe of 0.25 inch passes centrally through the sample kept on crisp support rig and a corresponding force deformation curve was plotted.

Firmness was obtained as the count of peaks in the graph and expressed in Newton (N) (Akinbode *et al.*, 2010). The firmness of the dried capsules is important and the value obtained were analysed statistically.

3.9.2. Chemical parameters

Chemical parameters viz., moisture, chlorophyll, essential oil of treated cardamom capsules and flavor profile of essential oil were recorded. Residual analysis of treated cardamom capsules were also carried out.

The samples for chemical analysis were prepared (AOAC, 1999) as follows a) reduction in volume b) particle size and c) thorough mixing of the samples so that the portion used for analysis represented the average composition of the entire mixture.

3.9.2.1. Moisture

Moisture content was determined by toluene distillation method using Dean and Stark apparatus and expressed in percentage (Pruthi, 1999) using the formula.

$$\text{Moisture (\%)} = \frac{\text{Vol of water (ml)}}{\text{Wt of samples (g)}} \times 100$$

3.9.2.2. Chlorophyll content in the rind of the capsules

Chlorophyll content in the rind of the capsule was determined using a spectrophotometer (Arnon, 1949). 5g of powdered cardamom rind was mixed with 10ml of DMSO: 80 % acetone mixture (1:1) and incubated overnight at room temperature for complete extraction of pigments. The colored solution was decanted centrifuged at 5000 rpm for 5 minutes. The volume was made up to 25ml with DMSO-acetone mixture and the absorbance was read at 645 and 663nm using a spectrophotometer and expressed in mg chlorophyll/g sample.

$$\text{Total chlorophyll} = 8.02(A_{663}) + 20.2(A_{645}) \times [V/1000 \times W],$$

Where V = Final volume of the extract

W = Fresh weight of the rind of capsules

3.9.2.3. Essential oil.

Essential oil was extracted by hydro distillation method using modified Clevenger apparatus (Pruthi, 1999) on dry whole capsule weight basis. Thrity gram dried cardamom capsule was crushed and subjected to hydro distillation for three hours. The oil collected were dried over anhydrous sodium sulphate and volatile percentage of oil was computed on volume by weight basis using the formula,

$$\text{Volatile oil (V/W)} = \frac{\text{Volatile oil (ml)}}{\text{Weight of the sample (g)}} \times 100$$

3.9.2.4. Flavour component in essential oil.

The flavour profile of essential oil was carried out using Gas Chromatography-Mass Spectrometry (GC-MS) technique (Plate 4).

For this thirty gram of dry whole cardamom was grinded and subjected to hydro distillation with a Clevenger type apparatus and extracted for three hours with 500ml water. The essential oil was collected, dried under anhydrous sodium sulphate and stored at 4^0 C until used. The separation and identification of volatile compounds was carried out using Gas Chromatography coupled to Mass Spectrometry (GC-MS).

Flavour components in essential oil were estimated using Gas Chromatography-Mass Spectrometry (GC-MS) technique. Gas Chromatography Mass Spectrometry (GC- MS) is a sophisticated technique whereby mass spectrometry acts as a detector for the compounds separated by a gas chromatography. The isolated compounds are illustrated in the form of a series of peaks in a Total Ion Chromatogram (TIC). Modern GC-MS equipment have

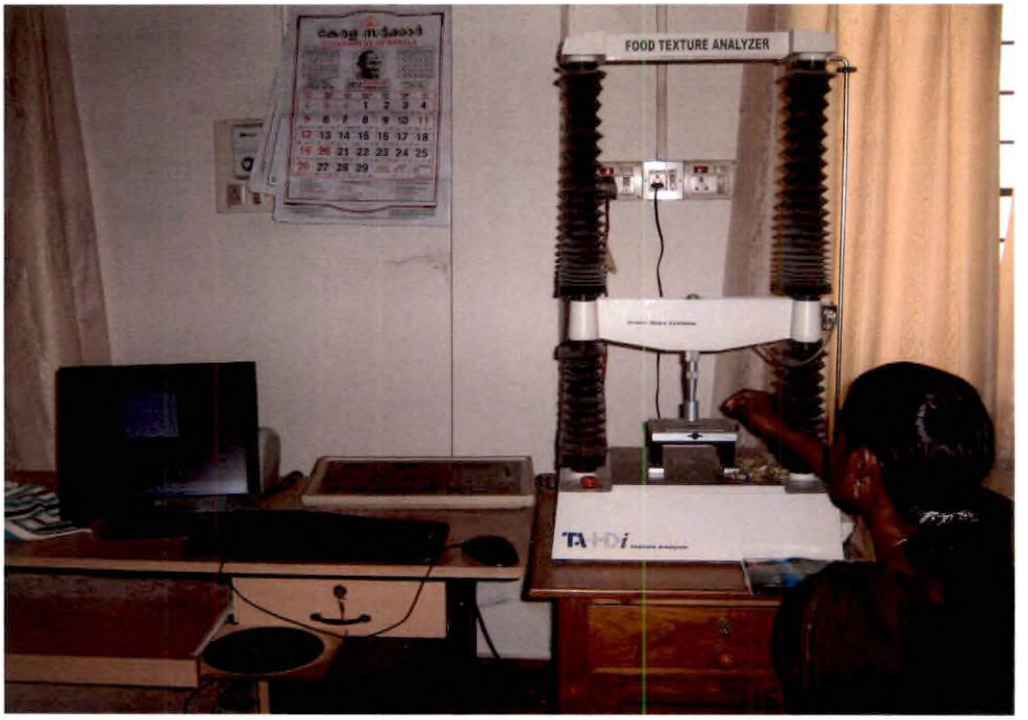

Plate 3. Instrumental measurement of texture of small cardamom using Food Texture Analyzer

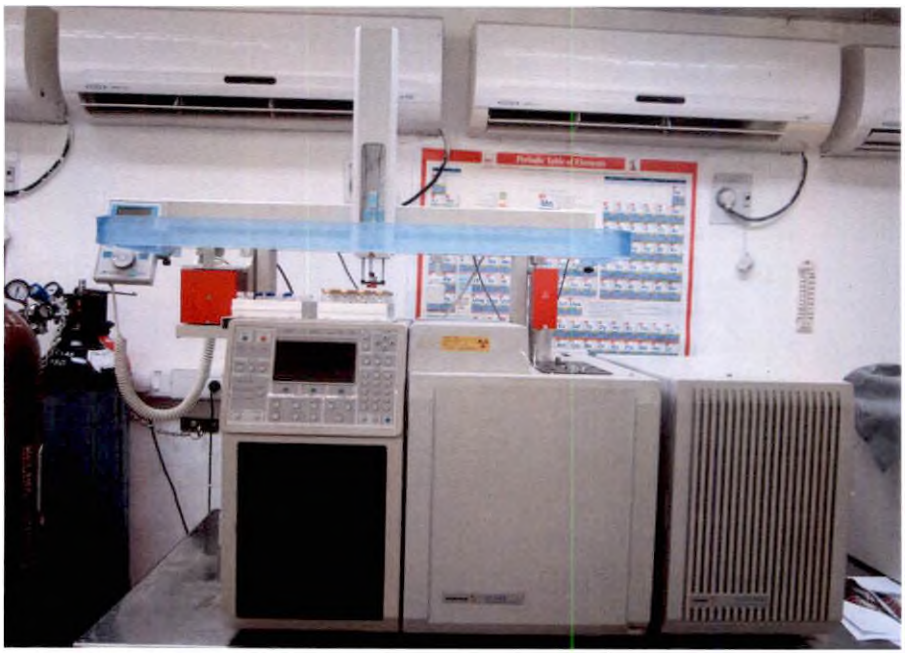

Plate 4. Gas chromatography Mass spectrometry

computerized libraries and advanced search systems. Mass spectrum of each compound detected can be instantaneously taken and searched through thousands of mass spectra contained in computerized libraries for identification. Mass spectral data alone cannot always be sufficient for correct identification and retention data should also be available for comparison. If a compound shows identical mass spectrum and retention data with a known compound then, they are considered identical. However, in cases of doubt, co-injection with a standard sample of the predicted compound, or running the same oil in a column with different polarity should be applied. The ideal solution to the problem could be the isolation of the compound in sufficient quantity to take a Nuclear Magnetic Radiation measurement or to complement the analysis with Fourier Transform Infrared (FT –IR) data. In case of new compounds, analysis of fragmentation data gives a clue to its chemical structure (Baser, 1995).

The essential oils were directly analysed by gas chromatography coupled to mass spectrometry (GC-MS) (computerized system comprising a 3800 gas chromatograph coupled to a Saturn 2200 mass spectrometer) using a fused –silica –capillary column with an apolar stationary phase Varian factor four capillary column VF-5ms (30 M x 0.25 MM) I.D,DF=0.25.GC –MS were obtained using the following conditions: carrier gas- He; flow rate 1.0mL/min; split 1:20; injection volume 1microL; injection temperature 220^{0}C; oven temperature progress from 60 to 246^{0}C at 3^0/min, from 246 - 300^{0}C at 20^{0}C/min and holding at 300^{0}C for 30 min; the ionization mode used was electronic impact at 70Ev. Identification of the components was achieved from their relative retention indices (RRI) on VF-5ms column, determined with reference to an homologous series of C_8 – C_{28} *n*-alkanes and by a comparison of their mass spectral fragmentation patterns with those stored in the data bank (NIST library) and the literature.

3.9.2.5. Residues of chemicals in treated cardamom

Pre treated cardamom capsules were analyzed to know the percentage of residue of sodium in sodium carbonate (1%), sodium hydroxide (1%) and sodium bicarbonate (1%), potassium in potassium carbonate (1%), magnesium in magnesium sulphate (1%), ascorbic acid in ascorbic acid (0.1%), citric acid in citric acid (0.1%), naphthalene acetic acid in naphthalene acetic acid (500ppm), polyethylene glycol in polyethylene glycol (0.1%) and copper in copper acetate (1%) treated cardamom capsules.

3.9.2.5.1. Sodium content

Sodium content in capsules treated with sodium carbonate (1%), sodium hydroxide (1%) and sodium bicarbonate (1%) were estimated by nitric-perchloric acid (9:4) digestion and flame photometry (Jackson, 1973) and expressed in mg/100 g of sample.

3.9.2.5.2. Potassium content

Potassium content in capsules treated with potassium carbonate (1%) was estimated by nitric-perchloric acid (9:4) digestion followed by flame photometric (Jackson, 1973) and expressed in mg/100 g of sample.

3.9.2.5.3. Magnesium content

Magnesium content in capsules treated with magnesium sulphate (1%) was estimated by nitric – perchloric acid (9:4) digestion and Versanate titration (Piper, 1966) and expressed in mg/100 g of sample.

3.9.2.5.4. Ascorbic acid content

Ascorbic acid content in capsules treated with ascorbic acid was estimated as per (Saini *et al.* 2001) and expressed as mg/100 g of sample. The difference in the

ascorbic acid content of treated and control sample corresponds to the residue of ascorbic acid.

3.9.2.5.5. Citric acid content

The procedure consisted of oxidation of citric acid by potassium permanganate in the presence of bromine (Pucher *et al.*, 1936). The pentabromoacetone produced was extracted from the oxidation mixture with petroleum ether and treated with aqueous sodium sulfide. The coloured substance that formed in the aqueous phase was stabilized by the addition of pyridine and the intensity of colour was determined in a spectrophotometer. The calibration curve was prepared by analyzing a series of solutions that contain from 0.1 to 1.0 mg. of citric acid, the preliminary boiling and treatment with bromine being omitted. From the curve the value can be found out.

3.9.2.5.6. Naphthalene acetic acid content

Naphthalene acetic acid content in treated capsules was estimated by titrimetric method. Five gram of powdered sample was suspended in 50ml of water and kept for two hours. After two hours extract was made up to 50ml. To this two drops of methyl orange indicator was added and titrated against 0.001N sodium carbonate. Appearance of yellow colour indicated the end point and the volume of sodium carbonate was noted. From the titre value and normality, the amount of naphthalene acetic acid in treated as well in control samples was calculated and expressed in percentage (Sadasivam and Manickam, 1992).

The difference in the naphthalene acetic acid content of treated and control sample corresponds to the residue of naphthalene acetic acid.

3.9.2.5.7. Polyethylene glycol content

The Polyethylene glycol (PEG) 1500 was estimated by infrared spectroscopy using carbon tetrachloride as the solvent after evaporation of the sample (Davis and Shields, 1968).

3.9.2.5.8. Copper content

Copper content in cardamom capsules treated with copper acetate (1%) was estimated nitric-perchloric acid (9:4) digestion and read using atomic absorption spectrophotometer (Hesse, 1971) and expressed in mg/100 g of sample.

3.9.3. Sensory observations

Sensory evaluation of cardamom capsules were done by a ten member semi trained panel to determine the sensory qualities of the treated capsules (Pruthi, 1999). Ten panelists were selected from among the scientists, students and Research Associates in the Department of Processing Technology and Department of Home Science, College of Agriculture, Vellayani. Sixty six differently coded samples were given to the panelists for sensory evaluation and the panelists were asked to score each sample for different attributes like apperance, colour, flavour, texture, taste and overall acceptability using a nine point hedonic scale (Appendix. I).

Like extremely	- 9
Like very much	- 8
Like moderately	- 7
Like slightly	- 6
Neither like nor dislike	- 5
Dislike slightly	- 4
Dislike moderately	- 3
Dislike very much	- 2
Dislike extremely	- 1

The overall acceptability was obtained as the combined score of all the attributes scored.

3.10. EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

Experiments were laid out in completely randomized design (CRD) and analysis of sensory evaluation was done using Kruskal-Wallis one way analysis of varience technique (Kruskal and Wallis, 1952).The physical and chemical characters of pre treated cardamom capsules cured under conventional and modern curing method were analyzed using analysis of varience technique (Gomez and Gomez, 1984).

Results

4. RESULTS

The results of the investigation "Effect of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardamomum* (L.) Maton)" are presented in this chapter under the following headings.

4.1. Effect of pre treatments and curing methods on the physical characters of small cardamom.

4.2. Effect of pre treatments and curing methods on the chemical characters of small cardamom.

4.3. Effect of pre treatments and curing methods on the sensory quality of small cardamom.

The resultant product obtained after pre treatments and curing were evaluated for physical, chemical and sensory qualities.

4.1. Effect of pre treatments and curing methods on the physical characters of small cardamom

Pre treated and cured small cardamom capsules were analysed for the physical characters such as its boldness, bulk density, colour and texture. The data pertaining to these characters are presented in the following tables.

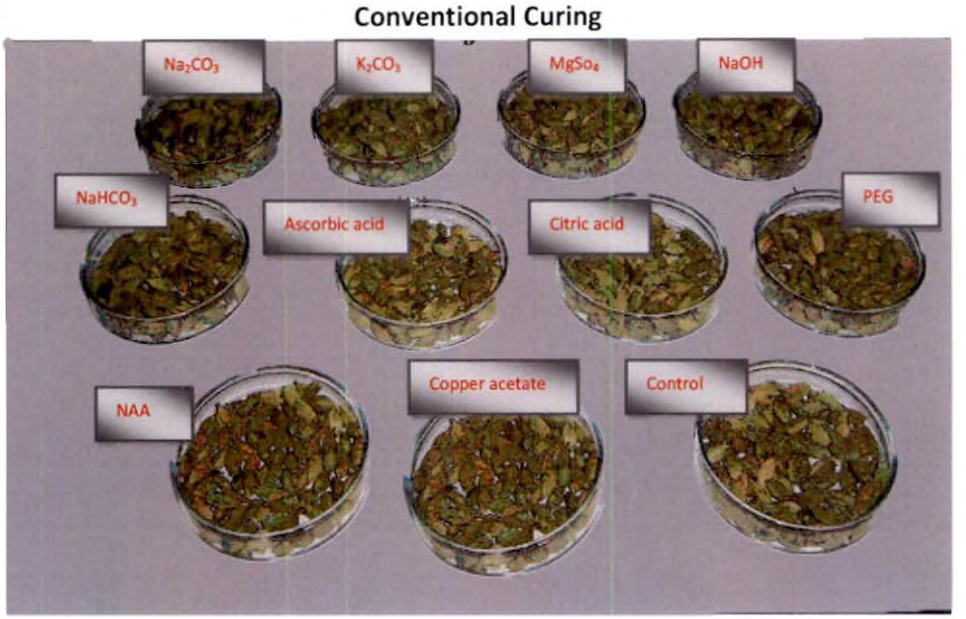

Plate 5. Pre treated and cured small cardamom capsules under conventional curing

Plate 6. Pre treated and cured small cardamom capsules under modern curing

Table 3 Abstract of ANOVA of physical characters (MSS)

Source	d.f	Boldness	Bulk density	Colour (a* value)	Total colour change value (ΔE)	Texture
Pre treatments	10	2.94	726.2	13.89**	34.99**	692.63
Curing methods	1	7.32	1355	3.09	3.61	6183
Pre treatments Vs Curing methods	10	2.94	61.7	1.61	1.46	268.58

a* is degree of redness to greenness (+ red; - green)

Table 3.1. Effect of pre treatments and curing methods on the boldness (mm) of small cardamom

Pre treatments	**Curing methods**		**Mean**
	Conventional curing	**Modern curing**	
Sodium carbonate (1%)	6.6	6.4	6.5
Potassium carbonate (1%)	6.53	6.4	6.47
Magnesium sulphate (1%)	6.53	6.53	6.53
Sodium hydroxide (1%)	6.63	6.43	6.53
Sodium bicarbonate (1%)	6.43	6.33	6.38
Ascorbic acid (0.1%)	6.47	6.53	6.5
Citric acid (0.1%)	6.6	6.33	6.47
Polyethylene Glycol (0.1%)	6.37	6.53	6.45
Naphthalene Acetic Acid (500ppm)	6.63	6.67	6.65
Copper acetate (1%)	6.5	6.33	6.42
Control (no treatment)	6.47	6.53	6.5
Mean	6.52	6.45	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.17	NS	
Curing methods	7.28	NS	
Pre treatments Vs curing methods	0.24	NS	

4.1.1. Boldness

No significance difference was noticed among pre treatments, curing methods as well as their interaction in the case of boldness (Table 3.1).

4.1.2. Bulk Density

The result of mean value of bulk density showed no significant difference among the different pre treatments, curing methods as well as their interaction (Table 3.2). The bulk density was thus observed as unaffected due to pre treatments and curing methods.

4.1.3. Colour (a* greenness)

The colour read using spectrophotometer showed significant difference among pre treatments (Table 3.3). The colour was not significant under different curing methods as well as between pre treatments curing methods interaction with respect to greenness.

Among the pre treatments capsules treated with 1% sodium hydroxide, 1% sodium carbonate, 1% potassium carbonate, 1% magnesium sulphate and control were on par, with respect to mean value towards greenness.

However the mean value towards greenness was more in cardamom capsules treated with 1% sodium hydroxide (-2.94) followed by capsules treated with 1% sodium carbonate (-2.92).

4.1.4. Total colour difference (ΔE value)

The total colour difference value (**ΔE**) read using spectrophotometer showed significance difference among different pre treatments (Table3.4). The total colour difference value was not significant under different curing methods as well as between pre treatments curing methods interaction.

Among the pre treatments the mean value towards total colour difference value (**ΔE**) was more in cardamom capsules treated with 1% sodium hydroxide (57.65) followed by 1% sodium carbonate (57.18), 1% potassium carbonate (55.28) and 1% magnesium sulphate (55.25) treated capsules.

Plate 7. Sodium hydroxide (1%) treated small cardamom capsules under conventional curing

Plate 8. Sodium hydroxide (1%) treated cardamom capsules under modern curing

Table 3.2. Effect of pre treatments and curing methods on the bulk density (g/L) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	375.37	365.01	370.19
Potassium carbonate (1%)	365.42	348.09	356.75
Magnesium sulphate (1%)	371.88	360.89	366.38
Sodium hydroxide (1%)	378.99	367.7	373.34
Sodium bicarbonate (1%)	355.04	345.28	350.16
Ascorbic acid (0.1%)	349.97	336.92	343.45
Citric acid (0.1%)	368.16	364.79	366.48
Polyethylene Glycol (0.1%)	345.99	338.87	342.43
Naphthalene Acetic Acid (500ppm)	365.24	358.30	361.78
Copper acetate (1%)	343.21	349.49	346.35
Control (no treatment)	369.88	354.26	362.07
Mean	362.65	353.60	-
Treatment effects	**SE**	**CD**	
Pre treatments	10.83	NS	
Curing methods	4.62	NS	
Pre treatments Vs curing methods	15.31	NS	

4.1.5. Texture

The texture measured using the index firmness indicated no significant difference among different pre treatments and curing methods (Table 3.5). The pre treatments – curing methods interaction also did not differ significantly as observed from the statistical analysis.

Table 3.3. Effect of pre treatments and curing methods on colour (a*) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	-3.36	-2.48	-2.92
Potassium carbonate (1%)	-2.09	-2.01	-2.05
Magnesium sulphate (1%)	-1.36	-1.92	-1.64
Sodium hydroxide (1%)	-3.43	-2.44	-2.94
Sodium bicarbonate (1%)	-1.25	-0.54	-0.90
Ascorbic acid (0.1%)	1.16	-0.44	0.36
Citric acid (0.1%)	0.86	-0.17	0.35
Polyethylene Glycol (0.1%)	1.10	-0.15	0.48
Naphthalene Acetic Acid (500ppm)	1.86	0.12	0.99
Copper acetate (1%)	-0.5	-0.36	-0.44
Control (no treatment)	2.00	0.60	1.30
Mean	-0.46	-0.89	-
Treatment effects	**SE**		**CD**
Pre treatments	0.67		1.92**
Curing methods	0.29		NS
Pre treatments Vs curing methods	0.95		NS

Plate 9. Sodium carbonate (1%) treated small cardamom under conventional curing

Plate 10. Sodium carbonate (1%) treated small cardamom capsules under modern curing

Table 3.4. Effect of pre treatments and curing methods on total colour difference (ΔEValue) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	56.85	57.50	57.18
Potassium carbonate (1%)	55.24	55.32	55.28
Magnesium sulphate (1%)	55.15	55.35	55.25
Sodium hydroxide (1%)	58.07	57.22	57.65
Sodium bicarbonate (1%)	54.95	55.24	55.09
Ascorbic acid (0.1%)	51.37	53.12	52.24
Citric acid (0.1%)	52.23	52.20	52.21
Polyethylene Glycol (0.1%)	52.30	52.11	52.21
Naphthalene Acetic Acid (500ppm)	50.63	51.89	51.26
Copper acetate (1%)	53.30	52.87	53.08
Control (no treatment)	49.15	51.59	50.37
Mean	53.57	54.04	-
Treatment effects	**SE**	**CD**	
Pre treatments	1.10	3.12**	
Curing methods	0.47	NS	
Pre treatments Vs curing methods	1.55	NS	

Table 3.5. Effect of pre treatments and curing methods on the texture (N) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	199.02	180.7	189.86
Potassium carbonate (1%)	191.00	175.80	183.40
Magnesium sulphate (1%)	195.00	175.13	185.07
Sodium hydroxide (1%)	197.03	185.13	191.08
Sodium bicarbonate (1%)	191.66	181.29	186.47
Ascorbic acid (0.1%)	179.73	172.82	176.28
Citric acid (0.1%)	192.92	152.31	172.62
Polyethylene Glycol (0.1%)	181.59	180.23	180.92
Naphthalene Acetic Acid (500ppm)	193.49	148.24	170.87
Copper acetate (1%)	171.94	146.89	159.42
Control (no treatment)	171.07	152.98	162.02
Mean	187.68	168.32	-
Treatment effects	**SE**	**CD**	
Pre treatments	16.32	NS	
Curing methods	6.96	NS	
Pre treatments Vs curing methods	23.08	NS	

4.2. Effect of pre treatments and curing methods on the chemical characters of small cardamom

Chemical characters of small cardamom analysed included moisture content, chlorophyll content, essential oil content, flavour characteristics of essential oil and residual effect of chemicals on the pre-treated and cured cardamom. The data pertaining to these characters are presented in the following tables.

Table 4. Abstract of ANOVA of chemical characters (MSS)

Table 4.1. Abstract of ANOVA of moisture, chlorophyll and essential oil content of small cardamom (MSS)

Source	d.f	Moisture	Chlorophyll content	Essential oil content
Pre treatments	10	1.09**	0.001**	2.48**
Curing methods	1	7.37**	0.0007	1.64
Pre treatments Vs Curing methods	10	0.18	0.0003	0.82

Table 4.2. Abstract of ANOVA of flavour profile (ten compounds) of essential oil of small cardmom (MSS)

Source	d.f	1,8-cineole	α -terpinyl acetate	Limonene	Linalool	Sabinene	Trans - nerolidol	α-terpineol	Linalyl acetate	Myrcene	α – pinene
Pre treatments	10	11.79**	19.48**	0.99*	2.59**	5.15**	1.06**	0.45*	7.67**	1.55**	1.57**
Curing methods	1	10.18**	8.69*	0.59	0.68	2.37**	0.72**	4.19**	1.69**	0.23	0.75*
Pre treatments Vs Curing methods	10	0.70	0.25	0.79	0.13	0.77**	0.50**	0.25	0.04	0.25*	0.50**

Table 4.3. Abstract of ANOVA of residual effect of pre-treated small cardamom (MSS)

Source	Sodium		Potassium		Magnesium		Ascorbic Acid		Citric Acid		NAA		PEG		Copper	
	d.f	MSS	d.f	MSS	d.f	MSS	d.f	MSS	d.f	MSS	d.f	MSS	d.f	MSS	d.f	MSS
Pre treatments	3	2767.82**	1	392776**	1	4033.31**	1	290.08**	1	9.36**	1	4.81**	1	0.0037**	1	0.012**
Curing method	1	1027.04**	1	532144**	1	33.31	1	2.08	1	0.963**	1	0.00000047	1	0.0003**	1	0.00041
Pre treatments Vs Curing method	3	153.82**	1	28712	1	33.38	1	0.082	1	0.963**	1	0.00000047	1	0.0003	1	0.00008

Table 4.1.1. Effect of pre treatments and curing methods on the moisture content (%) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	9.4	9.87	9.63
Potassium carbonate (1%)	10.03	10.62	10.33
Magnesium sulphate (1%)	9.7	10.41	10.05
Sodium hydroxide (1%)	9.27	9.43	9.35
Sodium bicarbonate (1%)	10.23	10.43	10.33
Ascorbic acid (0.1%)	9.93	10.97	10.45
Citric acid (0.1%)	10.03	10.9	10.47
Polyethylene Glycol (0.1%)	10	10.8	10.40
Naphthalene Acetic Acid (500ppm)	9.77	11.1	10.43
Copper acetate (1%)	10.37	10.97	10.67
Control (no treatment)	10.47	11.07	10.77
Mean	9.93	10.60	-

Treatment effects	**SE**	**CD**
Pre treatments	0.24	0.69**
Curing methods	0.10	0.29**
Pre treatments Vs curing methods	0.34	NS

4.2.1. Moisture content

A significant difference in moisture content was noticed among pre treatments and curing methods (Table 4.1.1). There was no significant difference with respect to the interaction of pre treatments and curing methods.

Among the pre treatments maximum moisture content was reported from control followed by treatment with copper acetate. The minimum moisture content was noticed in cardamom capsules treated with 1% sodium hydroxide (9.35) and 1% sodium carbonate (9.63).

The moisture content of the pre treated cardamom capsules with 1% sodium carbonate, 1% sodium hydroxide and 1% magnesium sulphate were on par. The moisture content of cardamom capsules treated with 1% potassium carbonate, 1% magnesium sulphate, 1% sodium bicarbonate, 0.1% ascorbic acid, 0.1% citric acid, 0.1% Polyethylene Glycol, 500 ppm naphthalene acetic acid, 1% copper acetate and control treatment did not vary significantly among the pre treatments. The moisture content under conventional curing was less (9.93%) compared to modern curing method (10.60%).

4.2.2. Chlorophyll content

The chlorophyll content of small cardamom showed significant difference among the pre treatments (Table 4.1.2). However there was no significant difference among the conventional and modern curing methods. It had been observed that there was no significant difference with respect to the interaction between pre treatments and curing methods.

Under the pre treatments, the high chlorophyll content was recorded for cardamom capsules treated with 1% sodium carbonate (0.384mg/g) and it was found to be on par with sodium hydroxide (0.383mg/g) treated capsules. The next best treatment noted was potassium carbonate (1%) and magnesium sulphate (1%) showing chlorophyll content of 0.378mg/g. Least chlorophyll was noted among cardamom capsule treated with copper acetate (1%) .

Table 4.1.2. Effect of pre treatments and curing methods on the chlorophyll content (mg/g of sample) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	0.384	0.383	0.384
Potassium carbonate (1%)	0.374	0.383	0.378
Magnesium sulphate (1%)	0.376	0.372	0.374
Sodium hydroxide (1%)	0.383	0.384	0.383
Sodium bicarbonate (1%)	0.383	0.373	0.378
Ascorbic acid (0.1%)	0.322	0.367	0.344
Citric acid (0.1%)	0.346	0.359	0.353
Polyethylene Glycol (0.1%)	0.342	0.360	0.351
Naphthalene Acetic Acid (500ppm)	0.374	0.363	0.368
Copper acetate (1%)	0.338	0.346	0.342
Control (no treatment)	0.354	0.359	0.356
Mean	0.361	0.368	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.009	0.02**	
Curing methods	0.004	NS	
Pre treatments Vs curing methods	0.01	NS	

4.2.3. Essential Oil Content

A significant difference in essential oil content was noted among the different pre treatments (Table 4.1.3). The effect of curing methods as well as the interaction of pre treatments and curing methods however did not make any significant difference in the essential oil content.

Among different pre treatments the cardamom capsules treated with 1% sodium hydroxide, 1% sodium carbonate and 1% magnesium sulphate had shown higher essential oil content (5.83%, 5.58% and 5.42% respectively) and were on par. All other pre treatments were on par with respect to essential oil content.

Table 4.1.3. Effect of pre treatments and curing methods on the essential oil content (%) of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	6.1	5.07	5.58
Potassium carbonate (1%)	4.87	3.83	4.35
Magnesium sulphate (1%)	5.83	5	5.42
Sodium hydroxide (1%)	6.3	5.37	5.83
Sodium bicarbonate (1%)	4.2	3.87	4.03
Ascorbic acid (0.1%)	4.1	4.07	4.08
Citric acid (0.1%)	4.97	3.87	4.42
Polyethylene Glycol (0.1%)	3.8	4.97	4.38
Naphthalene Acetic Acid (500ppm)	4.63	4.7	4.67
Copper acetate (1%)	3.87	4.27	4.07
Control (no treatment)	4.4	4.6	4.5
Mean	4.82	4.50	
Treatment effects	**SE**		**CD**
Pre treatments	0.36		1.04**
Curing methods	0.16		NS
Pre treatments Vs curing methods	0.51		NS

4.2.4. Effect of pre treatments and curing methods on the flavour profile of essential oil of small cardamom

The gas chromatograms showed upto 150-200 peaks and upto 90 compounds were identified. All peaks have not been identified. Among the identified compounds the major ten compounds were statistically analysed and presented. The identified 90 compounds are listed below.

Table 4.2.1. Chemical compounds present in essential oil of small cardamom

Common name	Chemical name
α- pinene	Bicyclo [3.1.1]hept-2-ene,2,6,6-trimethyl
β – pinene	Bicyclo [3.1.1] heptanes 6,6-dimethyl-2- methylene
Sabinene	Bicyclo [3,1,0] hexane, 4 –methylene -1-[1-methyl ethyl]-
Myrcene	1,6-octadiene,7-methyl-3-methylene
α- phellandrene	2-methyl-5-(1-methylethyl)
Limonene	1-methyl-4-(1-methylethyl)-cyclohexene
1,8-cineole	1,3,3-trimethyl-2-oxabicyclo(2.2.2)octane
γ - terpene	1-methyl-4-(1-methylethyl)-1,4-cyclohexadiene
p- cymene	1-methyl-4-isopropylbenzene
Terpinolene	4-Isopropylidene-1-methyl-cyclohexane
Linalool	2,6-Dimethyl-2,7-octadien-6-ol
Linalyl acetate	1,6-Octadien-3-ol,3,7-dimethyl-,acetate
Terpinen -4-ol	3-cyclohexane -1-ol,4-methyl-1-(1-methylethyl)
α- terpineol	3-cyclohexene -1-methanol, α, α,4-trimethyl-,(S)-
α- terpinyl acetate	p-menth-1-en-8-yl acetate
Citronellol	6-octane- 1-ol,3,7-dimethyl
Nerol	2-cis-3,7-Dimethyl-2,6-octadien-1-ol
Geraniol	Trans-3,7-Dimethyl-2,6-octadien-1-ol
Metyl euginol	1-(3,4-Dimethoxyphenyl)-2-propene
Trans –nerolidol	trans-3,7,11-Trimethyl-dedeca-1,6,10-trien-3-ol
α- thujene	2-methyl-5-(1-methylethyl)bicycle[3.1.0]hex-2-ene

Camphene	Bicyclo[2,2,1], heptanes, 2,2- dimethyl -3-methylene –
α- terpinene	1-Isopropyl-4-methyl-1,3-cyclohexadiene
Cis-ocimene	cis-3,7-Dimethyl-1,3,6-Octatriene
Trans –ocimene	trans-3,7-Dimethyl-1,3,6-Octatriene
Toluene	Monomethyl benzene
p-dimethyl styrene	1-Methyl-4-(1-methylethenyl)-benzene
Cyclosativene	1,2α,4-Methenoindan,3aβ,4β,5,6,7.7a-hexahydro-5α-isopropyl-1β,7aβ-dimethyl
α - copane	Tricyclo[4.4.0.02,7]dec-3-ene,1,3-dimethyl-8-(1-methylethyl)-,
α - ylangene	Tricyclo[4.4.0.02,7]dec-3-ene,8-isopropyl-1,3-dimethyl-,(1S,2R,6R,7R,8S)-(+)-
γ - cadiene	Naphthalene
Acetic acid	Acetic acid 1-methyl-1-(4-methyl-5-oxo-cyclohex-3-enyl)-ethylester
Propionic acid	1-methyl-1-(4-methyl-3-cyclohexen-1-yl) ethyl 2-methylpropanoate
Butyric acid	1-Propanecarboxylic acid
2-methyl butyric acid	2-methyl-iso valeric acid
3-methyl butyric acid	3-methylbutanoic acid ethyl ester
3-methyl butanol	Isopentan-1-ol
p-meth-3-en-1-ol	4-(1-Methylethyl)-1-methyl-2-cyclohexenol
Cuminyl alcohol	4-(1-methylethyl)benzenemethanol
p-cresol	1-Hydroxy-4-methylbenzene
Carvacerol	2-methyl-5-isopropylphenol
Thymol	1-Hydroxy-5-methyl-2-isopropylbenzene
Carbonyls	carbon oxide sulphide
3-methyl butanal	3-Methylbutyric aldehyde
2-methyl butanal	2-Methylbutyric aldehyde
Pentanal	n-Valeric aldehyde

Furfural	2-furancarboxyaldehyde
8-acetoxycarvotanacetone	10H-phenothiazin-2-ol, 8-chloroo-10-[3-dimethyl amino], propyl-acetate[ester]
Cuminaldehyde	4-isopropylbenzaldehyde
Carvone	2-Cyclohexen-1-one,2-methyl-5-(1-methylethenyl)-
Pinole	Cis-pinonic acid
Terpinyl-4-ylacetate	p-menth-1-en-8-yl acetate
α -terpinene propionate	p-menth-1-en-8-yl propionate
Dihydro – α – terpinyl acetate	p-8-menthanyl acetate
Styrene	Isopropenyl toluene
α - terpinyl propionate	p-menth-1-en-8-yl propionate
3-boranol	Bicyclo[2,2,1]heptan-2-ol
Bornyl acetate	1,7,7-Trimethylbicyclo(2.2.1)heptan-2-ol acetate
Methyl nerolate	cis-2,6-Octadienoic acid, 3,7-dimethyl-methyl ester
Gurjunene	7-isopropenyl-1,4-dimethyl-1,2,3,3a,4,5,6,7-octahydroazulene
Cadinene	1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-
Guajene	1,2,3,4,5,6,7,8-octahydro-1,4-dimethyl-7-(1-methylethyl)-
Cymene	p-Isopropylmethybenzene
Retinal	2,4,6,8-Nonatetraenal,3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)
Thujene	1-isopropyl-4-methylenebicyclo [3,1,0]hexene
Caryophyllene	Bicyclo [7,2,0]undec-4-ene,4,11,11-trimethyl-8-methylene-,(E)-(1R,9S)-(-)
Isogeraniol	3,6-octadien-1-ol, 3,7-dimethyl-(Z)-
Cumene	2-Phenylpropane
Safranal	2,6,6-Trimetyl-1,3-cyclohexadiene -1-carboxaldehyde

Deoxy lycorenine	Lycorenan, 9,10 –dimethoxy -1-mehyl-
Cis-5-octane-1-ol	5-octaen-1-ol,(Z)-
Pinene oxide	2,7,7-trimethyl-3-oxatricyclo[4.1.1.02,4]octane
α - thujene	2-methyl-5-(1-methylethyl)-bicyclo[3,1,0]hex-2-ene
Octane	Octatriene
Geranyl toluate	3,7-Dimethyl-2,6-octadienyl phenylacetate
Cinnamic acid	Trans-3-Phenyl-2-propenoic acid
L-tyrosine	A-Amino-β-(4-hydroxyphenyl)propionic acid)
Linolenin	9,12,15-octadecatrienoic acid
Camphosulfonyl chloride	Bicyclo [2,2,1]heptane-1-methanesulfonyl chloride,7,7-dimethyl-2-oxo-
Isolimone	3-isopropenyl-6-metyl-1-cyclohexene-,(3R-trans)-
Muurolene	[1α,4aα,8aα]-Naphthalene,1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-[1-methylethyl]-
Phthalic acid	1,2-benzenedicarboxylic anhydride
Masonine	1-Methyl-9,10-[methylenebis(oxy)lycorenan-7-one
2-carene	Bicyclo [4,1,0]hept-2-ene,3,7,7,-trimethyl-
Anthranilic acid	1,6-octadien-3-oll, 3,7-dimethyl-, 2-aminobenzoate
Deoxy lycorenin	Lycorenan 9,10-dimethoxy-1-methyl-
2-propenoic acid	1,3-butylene glycol dimethacrylate
1-verbenone	Bicyclo[3,1,1]hept-3-en-2-one, 4,6,6 –trimethyl-
Octatriene	trans-3,7-Dimethyl-1,3,6-Octatriene
Cyclohexanol	1-methyl -4-[1-methylethylidene]-

Table 4.2.2. Effect of pre treatments and curing methods on the 1, 8 - Cineole (%) in essential oil small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	37	35.8	36.4
Potassium carbonate (1%)	37.6	37	37.3
Magnesium sulphate (1%)	40.37	38.3	39.3
Sodium hydroxide (1%)	37.4	37.3	37.35
Sodium bicarbonate (1%)	36.3	36.4	36.35
Ascorbic acid (0.1%)	40.6	39.2	39.9
Citric acid (0.1%)	36	35.5	35.75
Polyethylene Glycol (0.1%)	38.6	38	38.3
Naphthalene Acetic Acid (500ppm)	40.1	38.5	39.3
Copper acetate (1%)	39.27	39	39.13
Control (no treatment)	38.2	37.8	38
Mean	38.31	37.53	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.46	1.32**	
Curing methods	0.20	0.56**	
Pre treatments Vs curing methods	0.65	NS	

4.2.4.1. Effect of pre treatments and curing methods on 1, 8-cineole (%) in essential oil of small cardamom

The 1, 8-cineole content in essential oil showed significant difference among pre treatments, curing methods. No significance difference was noticed due to pre treatments curing methods interaction (Table 4.2.2).

Among the pre treatments the capsules treated with 0.1 % ascorbic acid (39.9%), 500 ppm Naphthelene acetic acid (39.3%), 1% magnesium sulphate (39.3%) and 1% copper acetate (39.13%) were on par. The 1,8- cineole content in the essential oil of small cardamom of the control, pre treated with 1% sodium hydroxide and 1% potassium carbonate were on par.

Significant variation was noticed among curing methods also. The small cardamom capsules cured by conventional curing method showed higher concentration of 1, 8-cineole (38.31%) compared to modern curing (37.53%).

4.2.4.2. Effect of pre treatments and curing methods on α- terpinyl acetate (%) in essential oil of small cardamom

The α- terpinyl acetate content in essential oil showed significant difference among pre treatments and curing methods. The interaction however did not influence the α- terpinyl acetate (Table 4.2.3).

Among the pre treatments, the higher content of α- terpinyl acetate were reported from capsules treated with 1% sodium hydroxide (38.68%) and 1% sodium carbonate (37.03%) treated capsules.

Significant variation was noticed among curing methods also. The capsules treated with conventional curing method showed a higher concentration of α- terpinyl acetate (35.85%) compared to modern curing (35.13%).

Table 4.2.3. Effect of pre treatments and curing methods on the α-terpinyl acetate (%) in essential oil of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	37.2	36.87	37.03
Potassium carbonate (1%)	36.67	36.13	36.4
Magnesium sulphate (1%)	37.33	36	36.67
Sodium hydroxide (1%)	39.37	38	38.68
Sodium bicarbonate (1%)	37.57	36.4	36.98
Ascorbic acid (0.1%)	34.3	34	34.15
Citric acid (0.1%)	34.5	34	34.25
Polyethylene Glycol (0.1%)	35.47	35	35.23
Naphthalene Acetic Acid (500ppm)	34.48	34	34.24
Copper acetate (1%)	33	32	32.5
Control (no treatment)	34.5	34	34.25
Mean	35.85	35.13	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.49	1.40**	
Curing methods	0.21	0.60 *	
Pre treatments Vs curing methods	0.70	NS	

4.2.4.3. Effect of pre treatments and curing methods on limonene (%) in essential oil of small cardamom

In the essential oil of small cardamom capsules, limonene (%) content showed significant variation among pre treated cardamom. No significance difference was noticed between curing methods as well as among their interactions (Table 4.2.4).

Among the pre treatments, the content of limonene in the capsules treated with 0.1 % ascorbic acid (4.18%), 0.1 % citric acid (4.13%), 1% potassium carbonate (3.68%), 1% magnesium sulphate (3.5%) and 1% sodium bicarbonate (3.5%) were on par.

4.2.4.4. Effect of pre treatments and curing methods on linalool (%) in essential oil content of small cardamom

The linalool content in essential oil of small cardamom capsules showed significant difference among different pre treatments. No significance variation was noticed among curing methods as well as among their interactions.

Among the pre treatments, the linalool content in essential oil of small cardamom capsules pre-treated with 1% sodium hydroxide (4.42%), 1% sodium carbonate (4.23%), 1% potassium carbonate (4.2%), 1% magnesium sulphate (4.15%), 1% sodium bicarbonate (4.08%) and 500 ppm naphthalene acetic acid were on par.

4.2.4.5. Effect of pre treatments and curing methods on sabinene (%) in essential oil content of small cardamom

The sabinene (%) in essential oil of small cardamom capsules showed significant difference among different pre treatments, curing methods as well as among their interactions (Table 4.2.6).

Among the pre treated cardamom capsules the highest sabinene content was noticed with the capsules treated with 1% copper acetate (4.75%).

Table 4.2.4. Effect of pre treatments and curing methods on the limonene (%) in essential oil of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	2.9	3.57	3.23
Potassium carbonate (1%)	4	3.37	3.68
Magnesium sulphate (1%)	2.5	4.5	3.5
Sodium hydroxide (1%)	3	3.53	3.27
Sodium bicarbonate (1%)	3.23	3.77	3.5
Ascorbic acid (0.1%)	4.33	4.03	4.18
Citric acid (0.1%)	4.23	4.03	4.13
Polyethylene Glycol (0.1%)	3.23	3.27	3.25
Naphthalene Acetic Acid (500ppm)	3.09	3.01	3.05
Copper acetate (1%)	3.05	2.9	2.97
Control (no treatment)	3.33	3	3.17
Mean	3.36	3.54	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.27	0.78*	
Curing methods	0.12	NS	
Pre treatments Vs curing methods	0.39	NS	

The sabinene content in essential oil of small cardamom capsules treated with 1% sodium carbonate (3.34%), 0.1% citric acid (3.28%) and capsules treated as control (3.06%) were on par.

Significant variation in sabinene content was noticed among conventional and modern curing methods. The mean sabinene content recorded from modern method was 2.93% while that from conventional was 2.55%.

The pre treatments and curing methods interaction also showed significant variation.

4.2.4.6. Effect of pre treatments and curing methods on trans nerolidol (%) in essential oil content of small cardamom

Trans neorolidol content in essential oil showed significant difference among different pre treatments, curing methods as well as among their interactions (Table 4.2.7).

Among the pre treatments significantly high variation in trans nerolidol content was noticed in untreated cardamom capsules (3.2%), followed by capsules treated with 500ppm naphthalene acetic acid (3.02%). Trans nerolidol content in the essential oil of small cardamom capsules treated with 1% potassium carbonate (2.65%), 1% sodium carbonate (2.58%), 1% copper acetate (2.48%) and 1% sodium bicarbonate (2.37%) were on par.

Curing methods showed significant variation of trans nerolidol content in essential oil. The modern curing method recorded a higher percentage of trans nerolidol content(2.51%) where as under conventional curing the content was only 2.31%. A significant variation was also noticed among the interaction of pre treatments and curing methods.

Table 4.2.5. Effect of pre treatments and curing methods on the linalool (%) in essential oil of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	4.47	4	4.23
Potassium carbonate (1%)	4.27	4.13	4.2
Magnesium sulphate (1%)	4.27	4.03	4.15
Sodium hydroxide (1%)	4.67	4.17	4.42
Sodium bicarbonate (1%)	4.17	4	4.08
Ascorbic acid (0.1%)	3.77	3.57	3.67
Citric acid (0.1%)	3.6	3.43	3.52
Polyethylene Glycol (0.1%)	2.13	2.01	2.07
Naphthalene Acetic Acid (500ppm)	3.8	4.17	3.98
Copper acetate (1%)	3.23	3.33	3.28
Control (no treatment)	4.03	3.33	3.68
Mean	3.86	3.65	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.22	0.64**	
Curing methods	0.09	NS	
Pre treatments Vs curing methods	0.31	NS	

4.2.4.7.Effect of pre treatments and curing methods on α- terpineol (%) in essential oil of small cardamom

The percentage of α- terpineol (%) content in essential oil of small cardamom showed significant difference among pre treatments and curing methods. No significance variation was observed among their interactions (Table 4.2.8).

Among the pre treatments, the capsules treated with 0.1% citric acid (3.27%), 1% sodium carbonate (3.23%), 500 ppm Naphthelene acetic acid (3.09%), 1% sodium hydroxide, 0.1% ascorbic acid (2.92%) and 1% sodium bicarbonate were on par with respect to the α- terpineol (%) content in essential oil.

Significant variation was noticed among curing methods also. Conventionally cured cardamom capsules showed highest percentage of α-terpineol content (3.11%) compared to modern curing method (2.61%).

4.2.4.8. Effect of pre treatments and curing methods on linalyl acetate (%) in essential oil content of small cardamom

The percentage of linalyl acetate content in essential oil showed significant difference among different pre treatments and curing methods. No significance variation was noticed among their interactions (Table 4.2.9).

The capsules treated with 1% sodium hydroxide (4.35%), 1% sodium carbonate (4.29%) and 1% magnesium sulphate (4.28%) were on par with respect to the linalyl acetate content in essential oil.

Significant variation was noticed among the curing methods also. Cardamom capsules treated with conventional curing method showed higher mean percentage of linalyl acetate (3.12%) compared to modern curing (2.80%).

Table 4.2.6. Effect of pre treatments and curing methods on the sabinene (%) in essential oil content of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	3.34	3.33	3.34
Potassium carbonate (1%)	1.83	2.12	1.98
Magnesium sulphate (1%)	2.7	2.67	2.68
Sodium hydroxide (1%)	2.93	2.5	2.72
Sodium bicarbonate (1%)	2.93	2.73	2.83
Ascorbic acid (0.1%)	1.74	3.10	2.42
Citric acid (0.1%)	3.43	3.13	3.28
Polyethylene Glycol (0.1%)	1.4	2.13	1.77
Naphthalene Acetic Acid (500ppm)	1.01	1.53	1.27
Copper acetate (1%)	4.57	4.93	4.75
Control (no treatment)	2.12	4	3.06
Mean	2.55	2.93	-
Treatment effects	**SE**		**CD**
Pre treatments	0.15		0.44**
Curing methods	0.06		0.19**
Pre treatments Vs curing methods	0.22		0.62**

4.2.4.9.Effect of pre treatments and curing methods on myrcene (%) in essential oil of small cardamom

The percentage of myrcene content in essential oil showed significant difference among pre treatments as well as among their interactions (Table 4.2.10). No significance variation was noticed between curing methods.

Significantly high content of myrcene was noticed in the essential oil of small cardamom capsules pre treated with 0.1% polyethylene glycol (2.8%), followed by 1% sodium bicarbonate (2.53%), 0.1% ascorbic acid (2.3%) and 1% copper acetate(2.25%) which were on par.

Significant variation was also noticed among the pre treatments curing methods interaction.

4.2.4.10. Effect of pre treatments and curing methods on α-pinene (%) in essential oil of small cardamom

The percentage of α-pinene content in essential oil showed significant difference among pre treatments, curing methods as well as among their interactions (Table 4.2.11).

Among the pre- treatments, significant variation in α-pinene (%) content was noticed between cardamom capsules treated with 0.1 % Polyethylene Glycol (3.32%) and 1% sodium bicarbonate (2.31%).

Significant variation was noticed among the curing methods also. The modern curing method turned out to be significantly superior (2.09%) in retention of α-pinene flavour components compared to conventional curing methods (1.88%).

Significant variation was also noticed among the pre treatments curing methods interaction.

Table 4.2.7. Effect of pre treatments and curing methods on the trans nerolidol (%) in essential oil of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	2	3.17	2.58
Potassium carbonate (1%)	1.96	3.33	2.65
Magnesium sulphate (1%)	2.04	1.93	1.99
Sodium hydroxide (1%)	2.10	2.09	2.09
Sodium bicarbonate (1%)	2.60	2.13	2.37
Ascorbic acid (0.1%)	2.02	2.02	2.02
Citric acid (0.1%)	1.97	2.43	2.20
Polyethylene Glycol (0.1%)	1.81	2.10	1.96
Naphthalene Acetic Acid (500ppm)	3.10	2.93	3.02
Copper acetate (1%)	2.50	2.47	2.48
Control (no treatment)	3.30	3.10	3.2
Mean	2.31	2.52	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.12	0.34**	
Curing methods	0.05	0.14**	
Pre treatments Vs curing methods	0.17	0.48**	

Table 4.2.8. Effect of pre treatments and curing methods on the α- terpineol (%) in essential oil content of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	3.33	3.12	3.23
Potassium carbonate (1%)	3.33	2	2.67
Magnesium sulphate (1%)	3.13	2.37	2.75
Sodium hydroxide (1%)	3.15	2.83	2.99
Sodium bicarbonate (1%)	2.93	2.7	2.82
Ascorbic acid (0.1%)	3.13	2.7	2.92
Citric acid (0.1%)	3.40	3.13	3.27
Polyethylene Glycol (0.1%)	3.17	2	2.58
Naphthalene Acetic Acid (500ppm)	3.18	3	3.09
Copper acetate (1%)	2.6	2.13	2.37
Control (no treatment)	2.83	2.67	2.75
Mean	3.11	2.61	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.17	0.49*	
Curing methods	0.07	0.21**	
Pre treatments Vs curing methods	0.24	NS	

Table 4.2.9. Effect of pre treatments and curing methods on the linalyl acetate (%) in essential oil content of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	4.37	4.21	4.29
Potassium carbonate (1%)	1.73	1.53	1.63
Magnesium sulphate (1%)	4.37	4.2	4.28
Sodium hydroxide (1%)	4.7	4	4.35
Sodium bicarbonate (1%)	2.03	1.53	1.78
Ascorbic acid (0.1%)	1.87	1.63	1.75
Citric acid (0.1%)	2.63	2.37	2.5
Polyethylene Glycol (0.1%)	3.7	3.5	3.6
Naphthalene Acetic Acid (500ppm)	4.2	3.7	3.97
Copper acetate (1%)	2.3	2.03	2.17
Control (no treatment)	2.43	2.13	2.28
Mean	3.12	2.80	-
Treatment effects	**SE**		**CD**
Pre treatments	0.12		0.33**
Curing methods	0.04		0.14**
Pre treatments Vs curing methods	0.16		NS

Table 4.2.10. Effect of pre treatments and curing methods on the myrcene (%) in essential oil content of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	1.93	2.08	2.01
Potassium carbonate (1%)	1.15	1.87	1.51
Magnesium sulphate (1%)	1.25	1.2	1.22
Sodium hydroxide (1%)	1.28	1.41	1.35
Sodium bicarbonate (1%)	2.57	2.5	2.53
Ascorbic acid (0.1%)	2.34	2.26	2.30
Citric acid (0.1%)	2.03	2.12	2.08
Polyethylene Glycol (0.1%)	2.77	2.83	2.8
Naphthalene Acetic Acid (500ppm)	1.02	2.01	1.52
Copper acetate (1%)	2.5	2	2.25
Control (no treatment)	2.13	1.97	2.05
Mean	1.91	2.02	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.14	0.40**	
Curing methods	0.06	NS	
Pre treatments Vs curing methods	0.20	0.57*	

Table 4.2.11. Effect of pre treatments and curing methods on the α-pinene (%) in essential oil content of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	1.83	1.73	1.78
Potassium carbonate (1%)	1.01	2.13	1.57
Magnesium sulphate (1%)	1.62	1.53	1.57
Sodium hydroxide (1%)	1.43	2.01	1.72
Sodium bicarbonate (1%)	2.50	2.12	2.31
Ascorbic acid (0.1%)	1.05	2.07	1.56
Citric acid (0.1%)	1.33	2.13	1.73
Polyethylene Glycol (0.1%)	3.63	3	3.32
Naphthalene Acetic Acid (500ppm)	2.13	2.15	2.14
Copper acetate (1%)	2	2.12	2.06
Control (no treatment)	2.10	2.03	2.06
Mean	1.88	2.09	-
Treatment effects	**SE**		**CD**
Pre treatments	0.16		0.45**
Curing methods	0.06		0.19*
Pre treatments Vs curing methods	0.22		0.64**

4.2.4. Effect of pre treatments and curing methods on residue of pre-treated chemicals of small cardamom

The content of sodium, potassium, magnesium, ascorbic acid, citric acid, naphthelene acetic acid, polyethylene glycol and copper in pre treated small cardamom capsules were analyzed to find the residue level of these chemicals and the results are represented in the tables.

Table 4.3.1. Sodium content (mg/100g) in small cardamom capsules treated with sodium carbonate (1%), sodium hydroxide (1%) and sodium bicarbonate (1%).

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Sodium carbonate (1%)	65	77.33	71.17
Sodium hydroxide (1%)	50.33	65	57.67
Sodium bicarbonate (1%)	40.33	65.33	52.83
Control	20.33	20.67	20.50
Mean	44.00	57.08	-
Treatment effects	**SE**	**CD**	
Pre treatments	2.12	6.35**	
Curing methods	1.49	4.49**	
Pre treatments Vs Curing methods	2.99	8.97**	

4.2.4.1. Sodium

The chemical analysis carried out to find the sodium content in the small cardamom capsules treated with sodium salts revealed a significant difference compared to control (Table 4.3.1). The significant difference was evident between curing methods as well as for pre treatments curing interaction.

Among the pre treatments highest mean value for sodium content was obtained for cardamom capsules treated with 1% sodium carbonate (71.17mg/100g). The pre treatments using 1% sodium hydroxide and 1% sodium bicarbonate showed sodium values which were on par (57.67 mg/100g and 52.83 mg/100g respectively). The cardamom which was not pre treated (control) showed a sodium content of 20.50 mg/100g. The modern curing method showed a higher mean content of sodium (57.08 mg/100g) compared to conventional curing method (44.0mg/100g).

4.2.4. 2.Potassium

The potassium content of small cardamom capsules pre-treated with 1% potassium carbonate showed a significance difference in potassium content compared to control (Table 4.3.2). A significance difference in the potassium content was noted among curing methods also. The interaction of pre treatments and curing did not significantly influence the potassium content of small cardamom capsules pre-treated with1% potassium carbonate.

The potassium content in small cardamom capsules pre-treated with 1% potassium carbonate showed a mean value of 2546.67 mg/100g. The potassium content of untreated cardamom capsules (control) was 2184.33mg/100g. Among the curing methods, the potassium content was more under the modern curing (2576.33mg/100g) compared to conventional curing (2155.17mg/100g).

Table 4.3.2. Potassium (mg/100g) content in small cardamom capsules treated with potassium carbonate (1%)

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Potassium carbonate (1%)	2385.0	2708.33	2546.67
Control	1925.0	2444.33	2184.33
Mean	2155.17	2576.33	-

Treatment effects	**SE**	**CD**
Pre treatments	66.35	216.38**
Curing methods	66.35	216.38**
Pre treatments Vs Curing methods	93.83	NS

4.2.4.3. Magnesium

The magnesium content in cardamom capsules treated with 1% magnesium sulphate showed significant variation compared to untreated capsules (control) (Table 4.3.3). However there was no significant variation between curing methods. The pre treatments-curing methods interaction was significant for the magnesium content of pre- treated small cardamom capsules. The magnesium noted in small cardamom capsules treated with 1% magnesium sulphate was 170mg/100g compared to control (133.33mg/100g).

4.2.4.4. Ascorbic acid

The content of ascorbic acid in small cardamom capsules treated with 0.1% ascorbic acid showed significant variation compared to control (Table 4.3.4). The variation was not significant with respect to curing methods as well as pre treatments and curing method interaction.

The ascorbic acid showed a residue value of 38.33mg/100g compared to 28.5mg/100g in control. Among the curing methods, the cardamom capsules treated with conventional method showed a value of 33.83mg/100g compared to 33mg/100g under modern curing, which was not significant statistically.

4.2.4.5. Citric acid

The citric acid treated cardamom capsules significantly differed from the untreated one with respect to the residue of citric acid (Table 4.3.5). There was also significant variation noticed between curing methods as well as between pre treatments – curing method interaction.

The mean residue value of citric acid noted was 1.77ppm compared to zero ppm in control. The mean residue value of citric acid was higher under conventional curing 1.17 ppm compared to 0.60 ppm under modern curing method.

Table 4.3.3. Magnesium (mg/100g) content in small cardamom capsules treated with magnesium sulphate (1%)

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Magnesium sulphate (1%)	170	170	170
Control	130	136.67	133.33
Mean	150	153.33	-
Treatment effects	**SE**	**CD**	
Pre treatments	3.73	12.15**	
Curing methods	3.73	NS	
Pre treatments Vs Curing methods	5.27	NS	

4.2.4.6. Naphthelene Acetic Acid (NAA)

Significant variation was noted in the residue of naphthalene acetic acid (NAA) in the small cardamom capsules pre treated with 500ppm of naphthalene acetic acid compared to untreated one (control) (Table 4.3.6). The variation in residue of naphthelene acetic acid (NAA) was however non significant among curing methods. The pre treatments- curing method interaction also did not significantly influence the residue of naphthelene acetic acid (NAA). The naphthelene acetic acid (NAA) treated small cardamom capsules recorded a residue value of 1.26ppm compared to zero value of untreated cardamom capsules (control). The naphthelene acetic acid (NAA) residue value was same under both conventional as well as modern curing method (0.63ppm), which was showed no significance.

4.2.4.7. Polyethylene Glycol (PEG)

The variation in the residue of Polyethylene Glycol in small cardamom capsules treated with 0.1% of Polyethylene Glycol (PEG) was significant compared to untreated cardamom capsules (Table 4.3.7). The significant variation was evident with respect to curing methods as well as between interaction of pre treatments and curing methods. The mean residue value of Polyethylene Glycol 0.1% (PEG) recorded among pre treated cardamom capsules were 0.035%. Residue level recorded in the untreated (control) cardamom capsules were zero.

The residue percentage of polyethylene glycol 0.1% (PEG) was highest under modern curing compared to (0.023%) under conventional curing method (0.013%).

4.2.4.8. Copper

The residue of copper in small cardamom capsules treated with copper acetate (1%) showed significant variation compared to control (Table 4.3.8). The variation was non significant between curing methods as well as between pre treatments curing interaction.

The residue of mean value of copper recorded in the copper acetate treated cardamom capsules were 0.29mg/100g compared to the untreated one (0.23mg/100g). Among the curing methods residue recorded in conventional method was 0.26mg/100g compared to 0.25mg/100g recorded under modern curing, showing that the residue level did not vary significantly.

Table 4.3.4. Ascorbic acid (mg/100g) content in small cardamom capsules treated with ascorbic acid (0.1%)

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Ascorbic acid (0.1%)	38.67	38.00	38.33
Control	29.00	28.00	28.5
Mean	33.83	33.00	-
Treatment effects	**SE**		**CD**
Pre treatments	0.986		3.22**
Curing methods	0.986		NS
Pre treatments Vs Curing methods	1.39		NS

Table 4.3.5. Citric acid (mg/100g) content in small cardamom capsules treated with citric acid (0.1%).

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Citric acid	2.33	1.2	1.77
Control	0	0	0
Mean	1.17	0.60	-
Treatment effects	**SE**	**CD**	
Pre treatments	3.118	0.102**	
Curing methods	3.118	0.102**	
Pre treatments Vs Curing methods	0.041	0.144**	

Table 4.3.6. Naphthalene acetic acid (NAA) (ppm) residue in small cardamom capsules treated with Naphthalene acetic acid (500ppm)

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Naphthalene acetic acid (500ppm)	1.26	1.26	1.26
Control	0	0	0
Mean	0.63	0.63	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.02	0.08**	
Curing methods	0.02	NS	
Pre treatments Vs Curing methods	0.037	NS	

Table 4.3.7. Polyethylene Glycol (PEG) (%) residue in small cardamom capsules treated with Polyethylene Glycol (0.1%)

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Polyethylene Glycol (0.1%)	0.025	0.045	0.035
Control	0	0	0
Mean	0.013	0.023	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.000004	0.00001**	
Curing methods	0.000004	0.00001**	
Pre treatments Vs Curing methods	0.000006	0.00002**	

Table 4.3.8. Copper (mg/100g) content in small cardamom capsules treated with copper acetate

Pre treatments	Curing methods		Mean value
	Conventional curing	Modern curing	
Copper (1%)	0.29	0.29	0.29
Control	0.23	0.22	0.23
Mean	0.26	0.25	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.006	0.02**	
Curing methods	0.006	NS	
Pre treatments Vs Curing methods	0.009	NS	

4.3. Effect of pre treatments and curing methods on the sensory quality of small cardamom

After pre treatments and curing the small cardamom were subjected to sensory evaluation. Sensory qualities such as appearance of product, colour, flavour, texture, taste and overall acceptability were analyzed to assess the level of acceptability.

The result of changes in organoleptic qualities are presented here

Table 5. Abstract of ANOVA of sensory characters (MSS)

Source	d.f	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Pre treatments	10	1.49**	1.18*	1.26*	0.06	1.24	0.74*
Curing methods	1	1.48	0.07	8.73**	1.64**	0.41	14.00**
Pre treatments Vs Curing methods	10	0.29	0.06	0.45	0.01	0.01	0.88*

Table 5.1. Effect of pre treatments and curing methods on appearance of small cardamom

Pre treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	7	7.3	7.17
Potassium carbonate (1%)	6.83	6.93	6.88
Magnesium sulphate (1%)	6.7	6.73	6.72
Sodium hydroxide (1%)	7	7.5	7.25
Sodium bicarbonate (1%)	6.9	6.8	6.85
Ascorbic acid (0.1%)	5.9	6.53	6.22
Citric acid (0.1%)	5.47	6.5	6
Polyethylene Glycol (0.1%)	6.37	6.1	6.43
Naphthalene Acetic Acid (500ppm)	6.5	6.43	6.3
Copper acetate (1%)	5.53	5.83	5.98
Control (no treatment)	5.73	6.66	5.78
Mean	6.36	6.66	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.29	0.82**	
Curing methods	0.12	NS	
Pre treatments Vs curing methods	0.41	NS	

4.3.1. Appearance

There was a significant difference in appearance among different pre treatments (Table 5.1). The curing methods as well as pre treatments curing methods interaction did not show any significant difference.

The mean scores for appearance were highest for cardamom capsules treated with 1% sodium hydroxide (7.25). The pre treatments using 1% sodium hydroxide, 1% sodium carbonate, 1% potassium carbonate, 1% magnesium sulphate, 1% sodium bicarbonate and 0.1% poly ethylene glycol did not vary among each other in appearance. The least mean score for appearance was among the control treatment.

4.3.2. Colour

The colour scored by sensory observation showed significant difference for the pre treatments (Table 5.2). However there was no significant difference among different curing method as well as among the interaction between pre treatments and curing methods.

Among the pre treatments maximum score was noticed in cardamom capsules treated with 1% sodium hydroxide (7.5) followed by 1% sodium carbonate treated cardamom capsules (7.47). The cardamom capsules treated with 1% sodium hydroxide, 1% sodium carbonate, 1% potassium carbonate and 1% magnesium sulphate were on par compared to control.

4.3.3. Texture

The mean score value for sensory texture did not show any significant difference among different pre treatments (Table 5.3). The curing methods showed significant variation in texture. But the interaction between pre treatments and curing method did not show any significance. The conventional curing methods showed higher mean score value for texture (6.61) compared to modern curing method (6.30).

Table 5.2. Effect of pre treatments and curing methods on sensory colour of small cardamom

Pre –treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	7.4	7.53	7.47
Potassium carbonate (1%)	6.93	6.8	6.87
Magnesium sulphate (1%)	6.53	6.93	6.73
Sodium hydroxide (1%)	7.4	7.6	7.5
Sodium bicarbonate (1%)	6.53	6.8	6.67
Ascorbic acid (0.1%)	6.53	6.4	6.47
Citric acid (0.1%)	6.47	6.13	6.3
Polyethylene Glycol (0.1%)	6.27	6.53	6.4
Naphthalene Acetic Acid (500ppm)	6.6	6.6	6.6
Copper acetate (1%)	6.27	6.27	6.27
Control (no treatment)	6.2	6.27	6.23
Mean	6.65	6.72	-

Treatment effects	**SE**	**CD**
Pre treatments	0.27	0.78*
Curing methods	0.11	NS
Pre treatments Vs curing methods	0.39	NS

4.3.4. Taste

The cardamom capsules did not show any significant difference in taste among different pre treatments and curing methods (Table 5.4). There was also no significant difference in taste due to pre treatments and curing methods interaction.

4.3.5. Flavour

The mean score obtained for flavour scored through sensory analysis showed significant difference for the pre treatments as well as for curing method (Table 5.5). The interaction effects of pre treatments and curing methods did not show any significant difference.

Among the pre treatments the cardamom capsules treated with 1% sodium hydroxide scored a mean value of 6.9 followed by 1% sodium carbonate (6.72) and 1% magnesium sulphate (6.43) and these were on par. There was no variation among all other treatments.

Among the curing methods, the flavour was more for conventional curing (6.40) compared to modern curing (5.67).

4.3.6. Overall acceptability

Significant difference was noticed among different pre treatments with respect to overall acceptability (Table 5.6). A significant difference in overall acceptability was noticed among curing methods as well as among pre treatments- curing interaction. The conventional curing method showed a higher mean score value for overall acceptability (7.81) followed by modern curing with a mean score of 6.89.

Table 5.3. Effect of pre treatments and curing methods on sensory texture of small cardamom

Pre –treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	6.83	6.27	6.55
Potassium carbonate (1%)	6.7	6.3	6.5
Magnesium sulphate (1%)	6.66	6.3	6.5
Sodium hydroxide (1%)	6.73	6.6	6.67
Sodium bicarbonate (1%)	6.53	6.3	6.42
Ascorbic acid (0.1%)	6.47	6.2	6.33
Citric acid (0.1%)	6.6	6.3	6.47
Polyethylene Glycol (0.1%)	6.6	6.2	6.4
Naphthalene Acetic Acid (500ppm)	6.53	6.23	6.38
Copper acetate (1%)	6.46	6.13	6.3
Control (no treatment)	6.53	6.3	6.42
Mean	6.61	6.30	-

Treatment effects	**SE**	**CD**
Pre treatments	0.14	NS
Curing methods	0.05	0.16**
Pre treatments Vs curing methods	0.19	NS

Table 5.4. Effect of pre treatments and curing methods on sensory taste of small cardamom

Pre –treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	6.93	6.6	6.77
Potassium carbonate (1%)	6.73	6.53	6.63
Magnesium sulphate (1%)	6.4	6.2	6.3
Sodium hydroxide (1%)	7.3	7.3	7.3
Sodium bicarbonate (1%)	6.67	6.47	6.57
Ascorbic acid (0.1%)	6.27	6.13	6.2
Citric acid (0.1%)	6.27	6.13	6.2
Polyethylene Glycol (0.1%)	6.07	5.8	5.93
Naphthalene Acetic Acid (500ppm)	6.4	6.27	6.3
Copper acetate (1%)	6.13	6.07	6.1
Control (no treatment)	5.67	5.6	5.63
Mean	6.44	6.29	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.22	NS	
Curing methods	9.45	NS	
Pre treatments Vs curing methods	0.31	NS	

Table 5.5. Effect of pre treatments and curing methods on sensory flavour of small cardamom

Pre –treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	6.77	6.66	6.72
Potassium carbonate (1%)	6.33	4.83	5.58
Magnesium sulphate (1%)	6.6	6.27	6.43
Sodium hydroxide (1%)	7.07	6.73	6.9
Sodium bicarbonate (1%)	6.2	4.83	5.52
Ascorbic acid (0.1%)	6.47	5.17	5.82
Citric acid (0.1%)	6.33	4.97	5.65
Polyethylene Glycol (0.1%)	5.93	5.87	5.9
Naphthalene Acetic Acid (500ppm)	6.27	5.8	6.03
Copper acetate (1%)	6.13	5.53	5.83
Control (no treatment)	6.27	5.7	5.98
Mean	6.40	5.67	-

Treatment effects	**SE**	**CD**
Pre treatments	0.28	0.79*
Curing methods	0.12	0.34**
Pre treatments Vs curing methods	0.39	NS

Table 5.6. Effect of pre treatments and curing methods on the overall acceptability of small cardamom

Pre –treatments	Curing methods		Mean
	Conventional curing	Modern curing	
Sodium carbonate (1%)	8.07	8	8.03
Potassium carbonate (1%)	7.47	7.73	7.6
Magnesium sulphate (1%)	7.73	6.87	7.3
Sodium hydroxide (1%)	7.67	7.87	7.77
Sodium bicarbonate (1%)	7.6	6.47	7.03
Ascorbic acid (0.1%)	7.13	6.53	6.83
Citric acid (0.1%)	8.2	6.47	7.33
Polyethylene Glycol (0.1%)	7.8	6.33	7.07
Naphthalene Acetic Acid (500ppm)	7.8	6.33	7.07
Copper acetate (1%)	8.2	6.47	7.3
Control (no treatment)	8.2	6.67	7.43
Mean	7.81	6.89	-
Treatment effects	**SE**	**CD**	
Pre treatments	0.23	0.66*	
Curing methods	0.09	0.28**	
Pre treatments Vs curing methods	0.33	0.93*	

Discussion

5. DISCUSSION

The effect of pre treatments and curing methods on the quality characters of small cardamom was done to identify the best treatment. The evaluation was carried out based on physical, chemical and sensory qualities. The present study was undertaken using ten pre treatments evaluated under conventional and modern curing methods and best treatment under both curing methods were identified. A brief discussion regarding the results obtained is furnished here with.

5.1. Effect of pre treatments and curing methods on the physical characters of small cardamom

The effect of pre treatments like sodium carbonate-1%, potassium carbonate-1%, magnesium sulphate-1%, sodium hydroxide-1%, sodium bicarbonate-1%, ascorbicacid-0.1%, citric acid- 0.1%, polyethylene glycol- 0.1%, naphthalene acetic acid – 500ppm and copper acetate- 1% under conventional and modern curing on physical characters like boldness, bulk density, colour and texture is discussed here with.

5.1.1. Effect of pre treatments and curing methods on the boldness of small cardamom

The mean value for boldness did not show any significance difference with respect to pre treatments, curing methods as well as with respect to their interaction. This might be because boldness is a character mostly of the cultivar and could not generally be influenced by pre treatments as their curing methods.

5.1.2. Effect of pre treatments and curing methods on the bulk density of small cardamom

There were no significant difference among different pre treatments, curing methods as well as among pre treatments – curing methods interaction on the bulk density of small cardamom. The mean bulk density of cardamom capsules ranged from 342.43 to 373.34 g/l. This is in conformity with the findings of Kizhakkayil *et al.* (2006). The higher values of bulk density was noticed among sodium hydroxide (1%) treated cardamom capsules. Balakrishnan *et al.*(2011) and Gebreselassie (2012) studied moisture dependant physical

properties of cardamom capsules namely size, thousand capsule mass, sphericity, bulk density, true density, porosity, angle of repose, static coefficient of friction and hardness in the moisture content ranging from 8.41 to 24.8% and from 9.9% to 23.29% respectively on wet basis. They observed a decrease in bulk density with increase in moisture content which could be attributed to less weight gain due to the added moisture in relation to the concomitant volumetric expansion of the seeds.

The non significance of bulk density under different pre treatments, curing methods and pre treatments and curing methods interaction showed that in these conditions there was no influential increase in mass or volume as a result of different treatments and curing methods.

5.1.3. Effect of pre treatments and curing methods on the colour (a* greenness) of small cardamom

The colour of small cardamom was indicated by 'a' value, the green red spectrum ranging from -60 (green) to +60 (red) as well as by total colour difference (ΔE) value, which is the measure of total colour change.

The 'a' value is an index of greenness/ redness. The negative value indicates the nearness to greenness. In the results obtained the 'a' value for pre treatments like 1% of sodium hydroxide and sodium carbonate showed -2.94 and -2.92 respectively which shows the nearness to greenness. A similar observation was also noticed in the values of sensory evaluation of colour, where the values of sodium hydroxide, sodium carbonate and potassium carbonate were higher like 7.5, 7.47 and 6.87 respectively. Thus both the values of colour reading by spectrometer and the sensory evaluation were in conformity. These results indicate the superiority of pre treatments like sodium hydroxide and sodium carbonate.

Similar observation showing a negative value of -2.21, representing value indicating greenness was reported in kiwi fruit (Mohammadi *et al.*, 2008).

5.1.4. Effect of pre treatments and curing methods on the total colour difference value of (ΔE) of small cardamom

The total colour difference values (ΔE) were also significantly different compared to pre treatments. However the total colour difference values (ΔE) were not significantly affected by curing methods as well as by pre treatments curing methods interaction. The total colour difference values (ΔE) were higher for cardamom capsules treated with sodium hydroxide, sodium carbonate, magnesium sulphate, potassium carbonate and sodium bicarbonate which indicates their superiority over the pre treatments as well as control.

5.1.5. Effect of pre treatments and curing methods on texture of small cardamom

Pre treatments, curing methods as well as their interaction did not have any significant influence on the firmness of cardamom which is a measure of texture of small cardamom capsules measured by texture analyzer. The mean texture value of capsules of different pre treatments measured by texture analyzer varied from 159.42 to 191.08N.

Balakrishnan *et al.* (2002) reported a decrease of hardness a measure of texture from 19.62 ± 0.40 to 17.17 ± 0.13 N in the cardamom capsules of moisture content ranging from 8.41 to 24.87 % (w.b).

5.2. Effect of pre treatments and curing methods on the chemical characters of small cardamom.

The influence of pre treatments, curing methods and their interaction on the chemical characters of small cardamom namely moisture content, chlorophyll content, essential oil content and the flavour components in the essential oil are discussed in this chapter. The residue level of pre treated capsules were also analysed to identify whether they are present at toxic level in the treated cardamom.

5.2.1. Effect of pre treatments and curing methods on the moisture content of small cardamom

The moisture content of the pre treated small cardamom capsules as well as the pre treated capsules under two different curing methods showed significant

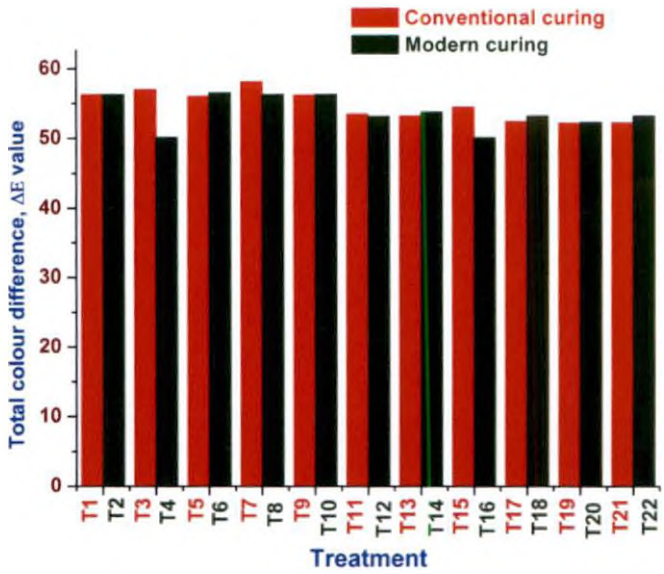

Fig.1.Effect of pre treatments and curing methods on colour of small cardamom (Total Colour Difference, ΔE Value)

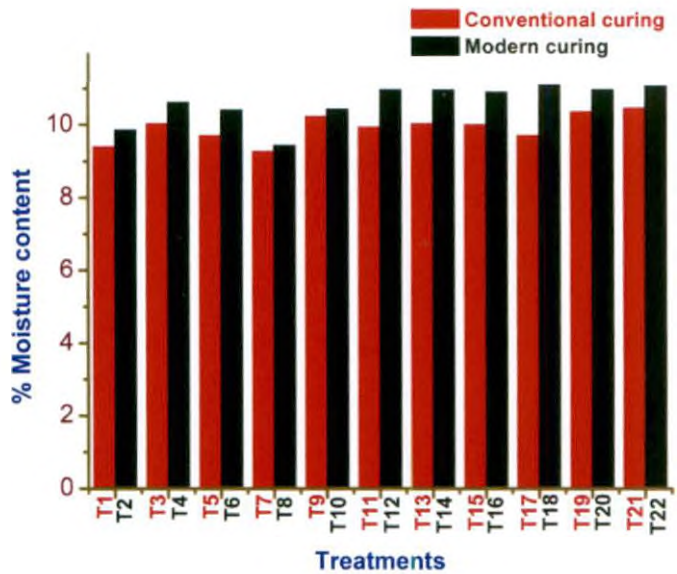

Fig.2. Effect of pre treatments and curing methods on the moisture content (%) of small cardamom

difference. However there was no significant interaction between pre treatment and curing methods.

The mean moisture content of pre treated cardamom capsules ranged from 9.35% to 10.77%. The moisture content of cardamom capsules treated with sodium hydroxide (1%) recorded minimum moisture content (9.35%). The moisture content of capsules treated as control showed the maximum moisture content (10.77%). The cardamom capsules treated with 1% of sodium hydroxide and sodium carbonate were on par with respect to moisture content. The lower the moisture content, higher the storability crispness and hardness. Balakrishnan *et al.* (2011) reported a linear decrease in hardness from 19.62± 0.40 to 17.17±0.13N with the increase in moisture content in dried cardamom capsules. The decrease in hardness was attributed by the increased moisture level which made the capsules softer. The increased moisture content from 8.41 to 24. 87% (wet basis) caused increased size and 1000 capsules mass from 8.34±0.08 to 9.78± 0.10mm and 115±2.61 to 146.3±4.36g respectively. A similar increase in dimension was noticed by Gebreselassie (2012) in dried cardamom capsules as a result of increase in moisture content. The increase in the dimension was attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the seeds.

Varkey *et al.* (1981) reported that moisture content above 10% was injurious to the chlorophyll and resulted in fading in the case of green cardamom. Among the curing methods the moisture content was less (9.93%) for curing under conventional method.

5.2.2. Effect of pre treatments and curing methods on the chlorophyll content of small cardamom

The pre treated cardamom capsules differed significantly for chlorophyll content. The chlorophyll content was similar under different curing methods. The pre treatments curing methods interaction also could not make any significant difference in chlorophyll content. Balakrishnan *et al.* (2002) reported drying of cardamom as one among the unit operation found to influence the green colour of the end product, mainly the total chlorophyll content.

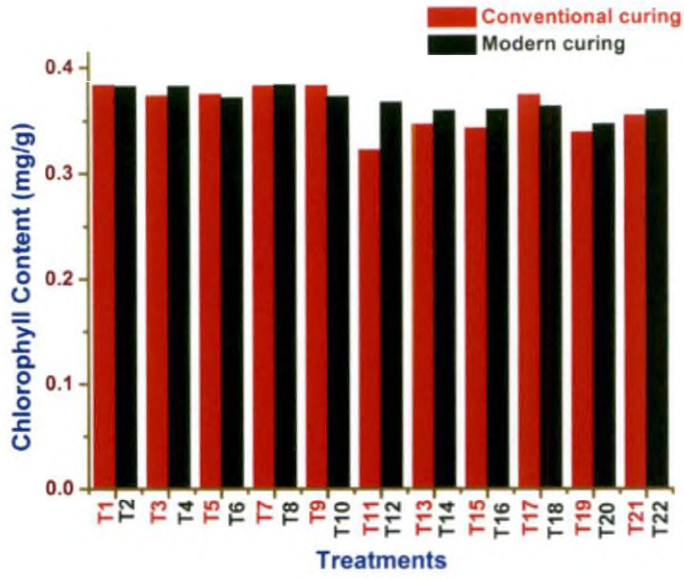

Fig.3. Effect of pre treatments and curing methods on the chlorophyll content (mg/g of sample) of small cardamom

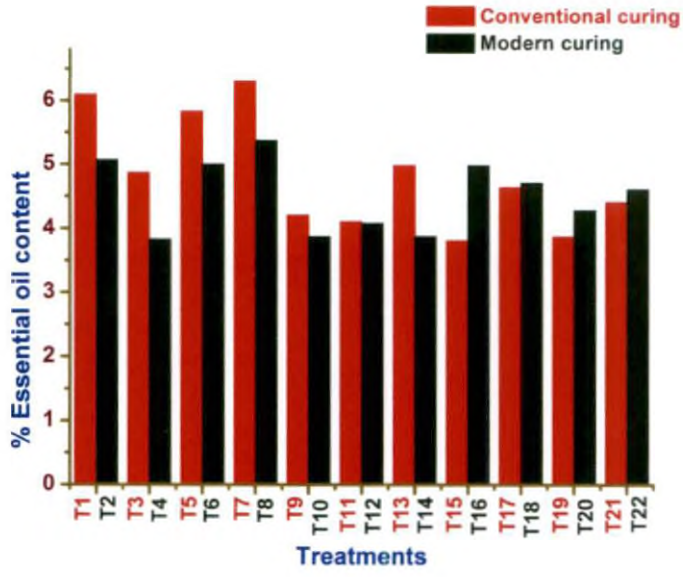

Fig.4. Effect of pre treatments and curing methods on the essential oil content (%) of small cardamom

Pruthi (1993) mentioned that the attractive green colour of cardamom which was due to chlorophyll could be stabilized to a great extent by steeping the cardamom in 2% Sodium carbonate solution for 10 minutes.

The effect of drying on the green colour retention analysed in terms of total chlorophyll content revealed higher total chlorophyll content when dried under intermittent spouting compared to continuous spouting. Only little difference in total chlorophyll was reported when there was increase in temperature from 40^0 to 50^0C. It was also concluded that lower slant angles and higher draft tube heights, which require higher airflow rates increased the loss of chlorophyll.

The non significance between the two curing methods revealed that the loss of chlorophyll during drying under conventional and modern curing methods are almost similar.

5.2.3. Effect of pre treatments and curing methods on the essential oil content of small cardamom

The results showed that different pre treatment significantly influenced the essential oil content. The influence of curing methods as well as the pre treatment curing interaction on the essential oil content was not significant. Maximum essential oil content of 5.83 was observed on the cardamom capsules treated with 1% sodium hydroxide followed by 1% sodium carbonate treated cardamom capsules (5.58).

Arjunan (1980) reported that cardamom contained 10% of volatile oil which was colourless with an agreeable camphoraceous odour and a pungent aromatic taste. The experiment conducted by Jyothikumar and Nanjan (1982) indicated the superiority of crushing the capsules. Seed, husk and rejects of cardamom compared to uncrushed cardamom, wherein the highest oil content (7.82%) was recorded in the crushed seed 4.40 percent from uncrushed seed, 5.49% from crushed capsules and 1.11% from uncrushed capsules. The rejected seeds could also be used for extracting cardamom oil since the crushed seeds yielded 5.83 percent.

Sayed *et al.* (1979) opined that the volatile oil content of cardamom seeds varies from 5.4 to 8% depending on the different types and varieties of cardamom. The seeds of Malabar variety contained 7.6 percent of oil on volume by weight basis. Jyothikumar and Nanjan (1982) recorded 7.82 percent on an average on the variety Malabar. Mathew (2000) observed that whole capsules and ground powder were used to impact aroma to the food product apart from seeds. The yield of cardamom oil on capsules basis was 6 to 8% and on seed basis was 8.5 to 12%.

The essential oil of our study ranged from 4.08 to 5.83 since the essential oil was extracted from the whole capsules. Raghavan *et al.* (1991) observed that the first few fractions of the distillate of cardamom were rich in the low boiling terpenes and 1, 8-cincole and the subsequent fractions rich in esters. It was also reported that the essential difference between Mysore and Malabar variety with regard to the composition of the volatile oil is in respect of the cineole content which was higher in the Malabar variety, attributed to its.

Anonymous (1977) weaved the delicate aroma quality of spice around 1,8-cineole and α-terpinyl acetate coupled with linalool, terpinen-1-01 (4) and a terpineole as well as the phenols, eugenol and methyl-and aceto eugenol.

The composition of cardamom oil had been studied by various workers (Gopalakrishnan and Narayanan, 1991; Purseglove *et al.*, 1982; Menon, 2000; and Marongia *et al.*, 2004) and the major compounds found were 1, 8-cineole (20-60%) and α-terpinyl acetate (20-55%). The chemical composition, flavonoid-phenolic contents and radical scavenging activity of four major varieties of cardamom were studied by Amma *et al.* (2010). The main constituents identified were terpinyl acetate ranging between 61.65% - 68.19% followed by cineol (7.23% - 11.76%).

The aroma differences in different source of cardamom were attributed to the proportion of the esters and 1, 8-cineole (Lewis *et al.*, 1966; Wijeskera and Jayawardena, 1973; Salzer 1975;).

5.2.4. Effect of pre treatments and curing methods on the flavour profile of essential oil of small cardamom

The essential oil extracted from different pre treatments under different curing methods analysed using Gas Chromatography-Mass Spectrometry technique identified ninety different compounds. Of this, ten main compounds (1, 8-cineole, α -terpinyl acetate, limonene, linalool, sabinene, trans nerolidol, α - terpineol, linayl acetate, myrcene, α -pinene) under pre treated small cardamom capsules under curing methods were statistically analysed and the results are discussed here with. The composition of cardamom oil had been studied by various workers (Gopalakrishnan and Narayanan, 1991; Purseglove *et al.*, 1982; Menon, 2000; and Marongia *et al.*, 2004) and the major compounds found were 1, 8-cineole (20-60%) and α-terpinyl acetate (20-55%).

According to Zachariah (2002) earlier chromatograms showed upto 31-33 peaks and upto 23 compounds were identified, while the improved procedure gave higher resolution with more than 150 peaks. All the peaks had not been identified. According to Raghavan *et al.* (1991) capillary column and gas chromatography has shown over 150 compounds in cardamom oil. While many of the identified compounds – alcohols, esters and aldehydes are commonly found in many spice oils, the dominance of ether 1,8 –cineole and the esters α – terpinyl and linalyl acetate in the composition, make the cardamom volatile oil a unique one (Lewis *et al.*, 1966; Salzer; 1975; Raghavan *et al.*, 1991; Korikanthimath *et al.*, 1997).

5.2.4.1. Effect of pre treatments and curing methods on 1, 8- cineole in essential oil of small cardamom

1, 8- cineole content in essential oil of small cardamom was significantly influenced by pre treatments as well as by curing methods .However the interactions did not influence the 1,8-cineole content.

The 1,8 –cineole content in the essential oil of the capsules treated with 0.1% ascorbic acid, 500 ppm naphthelene acetic acid, 1% magnesium sulphate and 1% copper acetate were on par. This was followed by the 1,8-cineole content of essential oil of small cardamom treated with 0.1%

polyethylene glycol, 1% sodium hydroxide and untreated capsules (control). Clark *et al.* (2000) suggested the biosynthesis of 1,8 – cineole from linalyl pyrophosphate. Zachariah (2002) reported as high as 41% of 1,8 – cineole content in the oil of variety Malabar and as low as 26.5 percent in the oil from variety Mysore. 1,8 – cineole (or Eucalyptol) is a biosynthetic dead end in many systems thus allowing accumulation of large quantities of this compound in plants.

Conventional curing method recorded highest 1, 8- cineole content (38.31%) in essential oil of small cardamom than modern curing method (37.53%). The loss in 1,8 cineole content in modern curing might be due to the quick curing of capsules compared to the conventional curing .

5.2.4.2. Effect of pre treatments and curing methods on α - terpinyl acetate in essential oil of small cardamom

The α-terpinyl acetate content in essential oil showed significant difference among pre treatments and curing methods. The interaction however did not influence the α-terpinyl acetate content.

The α-terpinyl acetate content in essential oil of small cardamom pre treated with 1% sodium hydroxide (38.68%) and 1% sodium carbonate (37.03%) were on par. According to many workers the ratio of 1,8-cineole to α – terpinyl acetate is a fairly good index of the purity and authenticity of cardamom volatile oil (Purseglove *et al.,* 1981). The volatile oil from variety Malabar represented by Coorg greens are "more camphory" in aroma due to the relatively higher content of 1,8-cineole. It is known that the early fraction during distillation are dominant in low boiling monoterpenes and 1,8-cineole. Techniques are available to remove these fractions by fractional distillation so that the remaining oil will have more α- terpinyl acetate which contributes to the mildly herbaceous, sweet, spicy flavour, that is pre dominant in the variety Mysore or the commercial grade commonly known as "Alleppey Green" (Govindarajan *et al.*, 1982). The combination of lower 1,8-cineole with its harsh camphory note and higher linalyl acetate with its sweet fruity – floral odour result in the relatively pleasant mellow flavour in the variety Mysore. According to Zachairah (2002) analysis of

germplasm collections conserved at the IISR Regional Station, Appangala, indicated variability in oil content and in the concentration of two important components of the oil 1,8-cineole and α- terpinyl acetate. Ratio of these two main components 1,8-cineole and α -terpinyl acetate determine the critical flavour of the oil and is around 0.7-1.4. Cardamom Research Centre, Appangala under the IISR, Calicut could collect many accessions from cardamom growing areas with the flavour ratio more than one. Selective breeding of the high quality accessions having low 1,8-cineole and high α- terpinyl acetate will go a long way in enhancing the total flavour quality of the Indian cardamom as per his observation. The results of the present experiment also shows higher terpinyl acetate in the cardamom capsules treated with 1% sodium hydroxide and sodium carbonate indicating the superiority of the above chemicals in enhancing the flavour.

5.2.4.3. Effect of pre treatments and curing methods on limonene in essential oil of small cardamom

Limonene content in essential oil of small cardamom showed significant difference among pre treatments. Among the pre treatments, the content of limonene in the capsules treated with 0.1 % ascorbic acid (4.18%), 0.1 % citric acid (4.13%), 1% potassium carbonate (3.68%), 1% magnesium sulphate (3.5%) and 1% sodium bicarbonate (3.5%) were on par. Ikeda *et al.* (1962) reported 23.3% of the cardamom oil as hydrocarbons with limonene as a major component.

Guenther (1975) reported that cardamom oil contained terpinene, sabinene, limonene, 1, 8 – cineole,α - terpinyl acetate, terpinen -4-yl formate and acetate and terpinen -4-ol. All plants employ the general isoprenoid pathway in the synthesis of certain essential substances. The mono and sesqui terpenes are regarded as diverging at the C_{10} and C_{15} stages respectively in the biosynthetic pathways. This, now well known pathway, begins with the condensation of 3-

acetyl CoA in two steps to form hydroxyl methyl –glutaryl-CoA which is reduced to mevalonic acid, the precursor of all isoprenoids. A series of phosphorylations and decarboxylation with the elimination of the C-3 oxygen function (as phosphate) yields isopentenyl pyrophosphate (IPP) (Mc Caskill and Croteau, 1995). This is isomerised to dimethylallyl pyrophosphate (DMAPP). This in turn leads to synthesis of geranyl pyrophosphate (GPP) and farnesyl pyrophosphate (FPP). The biosynthesis of monoterpenes, limonene and carvone, proceeds from geranyl diphosphate. The geranyl diphosphate is cyclised to (+) –limonene by mono terpene synthase. This intermediate is either stored in essential oil ducts without further metabolism or is converted by limonene-6-hydroxylase to (+)-trans carveol. This is oxidised by a dehydrogenase to (+)- carvone (Bouwmeester *et al.*,1998). Turner *et al.* (1999) demonstrated the localisations of limonene synthase. Studies in pepper mint (Gerhenzon *et al.*, 2000) suggested that the monoterpene biosynthesis is regulated by gene, enzymes and cell differenciation. Zachariah (2002) observed that locations also do play a role in altering the concentration of linalool, limonene, α- terpineol etc.

5.2.4.4. Effect of pre treatments and curing methods on linalool content (%) in essential oil of small cardamom

Linalool content in essential oil of small cardamom were significantly influenced by different pre treatments. Among the pre treatments, the linalool content in essential oil of small cardamom capsules pre-treated with 1% sodium hydroxide (4.42%), 1% sodium carbonate (4.23%), 1% potassium carbonate (4.2%), 1% magnesium sulphate (4.15%), 1% sodium bicarbonate (4.08%) and 500 ppm naphthalene acetic acid (3.98%) were on par. Zachariah (2002) observed that 1,8 cineole and α -terpinyl acetate together with terpene alcohols (linalool, terpinen-4 ol and α –terpinol) are important for the evaluation of aroma quality of cardamom. The cardamom treated with the above chemicals thus retain more flavour which might be due to the presence of more 1,8 cineole, α - terpinyl acetate and linalool.

5.2.4.5. Effect of pre treatments and curing methods on sabinene content (%) in essential oil of small cardamom

The sabinene content (%) in essential oil of small cardamom were significantly influenced by pre treatments, curing methods and their interaction. Among the pre treatments significant variation in sabinene content was noticed between cardamom capsules treated with 1% copper acetate (4.75%) which was the highest followed by 1% sodium carbonate (3.34%). The sabinene content in essential oil of small cardamom capsules treated with 1% sodium carbonate (3.34%), 0.1% citric acid (3.28%), capsules treated as control (3.06%) were on par. Govindarajan *et al.* (1982) reported that cardamom oil from Sri Lanka gave a high range of values for α pinene plus sabinene, 4.5 to 8.7 percent and linalool 3.6-6 percent and a wider range for the principal components 1,8- cineole, 27-36.1 percent and α – terpinyl acetate, 38.5-47.9 percent. Zachariah (2002) was of the opinion that some compounds such as α–thujene, sabiene, p-cymene, 2-undecanone, 2-trideconene, heptacosane or cis and trans-p-menth-2-en-1 ols were rarely detected in cardamom capsule.

Significant variation in sabinene (%) was noticed among conventional and modern curing methods. The mean sabinene content recorded from modern method was 2.93% while that from conventional was 2.55%. The pre treatments and curing methods interaction also showed significant variation.

5.2.4.6. Effect of pre treatments and curing methods on trans nerolidol content (%) in essential oil of small cardamom

Trans nerolidol content (%) in essential oil of small cardamom were significantly influenced by pre treatments, curing methods as well as among their interaction.

Among the pre treatments significantly high trans nerolidol content was noticed in untreated cardamom capsules (3.2%), followed by 500ppm naphthalene acetic acid (3.02%) and were on par. Trans nerolidol content in the essential oil of small cardamom capsules treated with 1% potassium carbonate (2.65%), 1% sodium carbonate (2.58%), 1% copper acetate (2.48%) and 1%

sodium bicarbonate (2.37%) were on par. Capsules cured by modern method showed highest trans nerolidol content (2.52%) compared to conventional curing (2.31%).

A significant variation was also noticed among the interaction of pre treatments and curing methods.

5.2.4.7. Effect of pre treatments and curing methods on α -terpineol content (%) in essential oil of small cardamom

The percentage of α –terpineol content in essential oil of small cardamom were significantly influenced by pre treatments and curing methods.

Among the pre treatments, the capsules treated with 0.1% citric acid (3.27%), 1% sodium carbonate (3.23%), 500 ppm Naphthelene acetic acid (3.09%), 1% sodium hydroxide, 0.1% ascorbic acid (2.92%) and 1% sodium bicarbonate were on par with respect to the α- terpineol (%) content in essential oil.

Significant variation was noticed among curing methods also. Conventionally cured cardamom capsules showed highest percentage of α-terpineol content (3.11%) compared to modern curing method (2.61%).

5.2.4.8. Effect of pre treatments and curing methods on linalyl acetate content (%) in essential oil of small cardamom

The percentage of linalyl acetate content in essential oil of small cardamom were significantly influenced by pre treatments and curing methods.

The capsules treated with 1% sodium hydroxide (4.35%), 1% sodium carbonate (4.29%) and 1% magnesium sulphate (4.28%) were on par with respect to the linalyl acetate content in essential oil. According to Govindarajan *et al.,* (1982) the combination of lower 1,8- cineole with harsh camphory note and higher linayl acetate with its sweet, fruity floral odour result in the relatively pleasant mellow flavour in the variety Mysore. Zachariah (2002) observed that 1,8 cineole and α -terpinyl acetate together with terpene alcohols (linalool, terpinen-4 ol and α –terpinol) are important for the evaluation of aroma quality of cardamom.

Significant variation was noticed among the curing methods also. Cardamom capsules treated with conventional curing method showed higher mean percentage of linayl acetate (3.12%) compared to modern curing (2.80%).

5.2.4.9. Effect of pre treatments and curing methods on myrcene content (%) in essential oil of small cardamom

The myrcene content in essential oil of small cardamom were significantly influenced by pre treatments as well as among their interaction. Significantly high content of myrcene was noticed in the essential oil of small cardamom capsules pre-treated with 0.1% polyethylene glycol (2.8%), followed by 1% sodium bicarbonate (2.53%), 0.1% ascorbic acid (2.3%) and 1% copper acetate (2.25%) which were on par.

Significant variation was also noticed among the pre treatments curing method interaction.

5.2.4.10. Effect of pre treatments and curing methods on α- pinene content (%) in essential oil of small cardamom.

The α-pinene content in essential oil of small cardamom were significantly influenced by pre treatments, curing methods as well as among their interaction. Among the pre- treatments, significant variation in α-pinene content was noticed among different pre treatments. The cardamom capsules treated with 0.1 % polyethylene glycol (3.32%) showed higher α- pinene content followed by 1% sodium bicarbonate (2.31%).

Significant variation was noticed among the curing methods also. The modern curing method turned out to be significantly superior (2.09%) in retention of α-pinene flavour components compared to conventional curing methods (1.88%).

Significant variation was also noticed among the pre treatments curing methods interaction.

5.2.5. Effect of pre treatments and curing methods on the residual effect of small cardamom

The cardamom capsules pre treated with sodium carbonate, sodium hydroxide, sodium bicarbonate, potassium carbonate, copper acetate, ascorbic acid, citric acid, naphthalene acetic acid and polyethylene glycol were subjected to the residue analysis and the results are discussed here.

5.2.5.1. Sodium in the cardamom capsules treated with sodium carbonate, sodium hydroxide, sodium bicarbonate and control treatment

The cardamom capsules treated with 1% of sodium carbonate, sodium hydroxide, sodium bicarbonate showed significant level of residues of sodium compared to control. Among the three pre treated sodium salts, sodium carbonate treated cardamom capsules recorded more residue of sodium (71.77mg/100g) compared to sodium hydroxide (57.67mg/100g) and sodium bicarbonate (52. 83mg/100g). The sodium content found in the control were 20.50mg/100g. The nutritional value of cardamom as put forward by United States Department of Agriculture accounts for 18mg per 100g of cardamom which is 1% of Recommended Dietary Allowance. This sodium level corresponds near value to the sodium content of untreated cardamom (control). The pre treatment with sodium carbonate, sodium hydroxide, sodium bicarbonate resulted in higher level of sodium. However the level of sodium is well within the toxic limit. The Dietary Approach to Stopping Hypertension (DASH) diet limits sodium between 1500mg and 2300 mg a day (Mayoclinic. n. d.). Hence the consumption of pre treated cardamom continaining more sodium will not be to the toxic level, since the use of cardamoms forms only very less in our daily diet. The higher values of sodium in sodium carbonate treated capsules may be due to the two molecules sodium involved unlike sodium hydroxide and sodium bicarbonate.

Among the curing methods more sodium content in modern curing was noted (57.08 mg/100g) compared to conventional curing (44 mg/100g). The modern curing requires only less time for curing (10-12 hours) compared to conventional curing (30 hours) during which the sodium might have decomposed

lost. This might be the reason for less sodium content observed under conventional curing.

5.2.5.2. Potassium in the cardamom capsules treated with potassium carbonate

The significant level of mean residue value for potassium was obtained in cardamom capsules treated with 1% potassium carbonate. The superiorly higher values of 2546.67 mg/100g of potassium had been recorded from potassium carbonate treated cardamom capsules compared to control (2184.33 mg/100g). The higher values of potassium in potassium carbonate treated cardamom capsules might be due to the residue of potassium from potassium carbonate. The untreated cardamom recorded a mean value of 2184.33 mg/100g. The United States Department of Agriculture (USDA) had reported a potassium content of 1119mg/100g of cardamom capsules (Leonard *et al.*, 2001). The potassium content of the untreated cardamom capsules noted was above the nutritional value reported by United States Department of Agriculture (USDA) which suggests a general higher level of potassium nutrition seen in the cardamom capsules of Idukki.

Among the curing methods a significant variation was noticed, with modern curing method resulted in higher potassium content 2576.33mg/100g compared to conventional curing 2155.17mg/100g. The higher potassium content in modern curing might be due to the less drying time of cardamom capsules under modern curing compared to the conventional curing.

5.2.5.3. Magnesium in the cardamom capsules treated with magnesium sulphate

The cardamom capsules treated with 1% magnesium sulphate produced significantly higher content of magnesium compared to control. The magnesium sulphate treated cardamom capsules recorded 170mg/100g of magnesium compared to 133.33mg/100g of untreated cardamom capsules. The pre treated cardamom capsules might have left some magnesium in the capsules which resulted in more magnesium content in pre treated cardamom compared to untreated cardamom capsules (control).

The magnesium content as observed by United States Department of Agriculture (USDA) was 229 mg / 100g of cardamom capsules. The magnesium content of treated as well as untreated was less than this value which suggests lower magnesium content in the cardamom capsules of Idukki.

No variation in magnesium content was noticed among different curing methods which suggests that the curing methods does not have an influence in the magnesium content of treated and untreated cardamom capsules.

5.2.5.4. Ascorbic acid in the cardamom capsules treated with Ascorbic acid

The ascorbic acid content of the pre treated cardamom capsules significantly differed from the control. The ascorbic acid of the pre treated cardamom capsules recorded a mean value of 38.33mg/100g compared to 28.5mg/100g of untreated (control) cardamom capsules. The higher ascorbic acid content noted in pre treated cardamom capsules might be due to the residue of ascorbic acid left after the pre- treatments.

No significant variation in ascorbic acid was noted between curing methods suggesting the fact that the drying methods could not influenced on the retention of ascorbic acid in cardamom capsules.

5.2.5.5. Citric acid in the cardamom capsules treated with Citric acid

Significant variation in residue of citric acid content of the pre treated capsules was noticed compared to control. The higher citric acid value in pre treated cardamom capsules (1.77ppm) might be due to the residue left after the treatment. The citric acid level in untreated cardamom was beyond the detectable limit. Among the curing methods also significant variation was noted. The higher citric acid content noticed in conventional curing (1.77ppm) might be due to the slow curing process which took, 36 hours for curing compared to 12 hours in modern dryer. The pre treatments curing methods interaction was also significant with respect to the residue of citric acid.

5.2.5.6. Naphthalene acetic acid (NAA) in the cardamom capsules treated with naphthalene acetic acid

The residue of naphthalene acetic acid pre treated cardamom capsules recorded a significant variation compared to untreated cardamom capsules

(control). The pre treated cardamom capsules recorded a mean residue level of 1.26ppm. No maximum residue limits (MRLs) for naphthalene acetic acid, its salts, ester and acetamide had been established in the Codex Alimentaries, the food code established by the UN's World Health Organization and the Food and Agricultural Organization, therefore issues of compatibility between Codex MRLs and US tolerance do not exist. Moreover, no Canadian or Mexican MRLs had been established for naphthalene acetates (Anonymous, 2007).

European Agency for the evaluation of medicinal products had reviewed all the toxicity studies submitted and had determined that the toxicity database was essentially complete to support a registration eligibility determination for all currently registered uses of naphthalene acetates. The tolerance listed under 40 Code of Federal Regulations (CFR) and 180.55(a) are for residues of 1-naphthalene acetic acid, the 40 CFR and 180.55(b) are for residues of the ethyl ester of 1- naphthalene acetic acid and 40 CFR and 180.309 are for residues of α–naphthalene acetamide and its metabolite, α-naphthalene acetic acid. According to 40 CFR and 180.3(d) (7), for commodities having both naphthalene acetic acid and naphthalene acetic acid metabolite tolerances, the total amount of residues calculated as naphthalene acetic acid, shall not exceed the higher of the two tolerances. The United States Environment Protection Agency (USEPA) had recommended that the Naphthalene Acetate earlier established for apples, pear and quince which was 1ppm should be lowered to 0.1ppm because the residue levels from the field data never exceeded 0.06 ppm (Anonymous, 2007).

The naphthalene acetic acid (NAA) residue in naphthalene acetic acid pre-treated cardamom showed 1.26 ppm which was a higher dose more than the recommended dose for apple, pear and quince. Hence pre treated naphthalene acetic acid would not be on safer side for consumption. The applied naphthalene acetic acid might not have disintegrated to limit the residue beyond the permitted maximum residue level. Among the curing methods no significant difference was noticed for the residual limit of naphthalene acetic acid.

5.2.5.7. Polyethylene glycol (PEG) in the cardamom capsules treated with polyethylene glycol

A significant variation in the residue of polyethylene glycol treated cardamom capsules was noted compared to untreated capsules (control). The polyethylene glycol treated cardamom capsules recorded 0.035% residue compared to control which could not record any residue of polyethylene glycol. Among the curing methods also significant variation was noticed with modern curing showing higher residue of polyethylene glycol (0.023%) compared to conventional curing (0.03%).

The polyethylene glycol (PEG) are prepared by polymerization of ethylene oxide and are commercially available over a wide range of molecular weights (en.Wikipedia.org/wiki/polyethylene glycol). Ethylene oxide purity criteria had been set for polyethylene glycol 6000 as ≤ 1mg/kg, Commission Directive 2000/63/EC. The committee had informed that the currently achievable detection limit for ethylene oxide was well below the specified purity criteria of 0.5 and 1mg/kg. The used and reported detection limit for ethylene oxide in Enterohemorrhagic *Escherichia Coli* (EHEC) is 0.2 mg ethylene oxide per kg cellulose as per the petitioner (OFCA,1996).The same limit had been used in the screening of spices for their ethylene oxide content (Fowles *et al.*,2001). The percentage of polyethylene glycol was 0.035% for pre treatment and 0.023% for modern curing method and 0.013% for conventional curing method which was far below the toxic level.

5.2.5.8. Copper content in the cardamom capsules treated with copper acetate

The copper content in the cardamom capsules treated with 1% copper acetate showed a significant difference compared to control. The residue of copper content was 0.29mg/100g for the pre treated and 0.23mg/100g for untreated (control). The copper content as revealed by the United States Department of Agriculture (USDA) for cardamom was 0.383 mg/100g according to the nutrition content in cardamom. Copper is heavy metals that are known to be toxic to human and are often impossible for the human body to metabolise.

Therefore its presence need to be controlled and should not exceed the Codex maximum residue limit to prevent a build up in the body over a period of time. American Spice Trade Association (ASTA) stated that typical heavy metals found in spices are lead, cadmium, zinc, tin, arsenic and copper (IOSTA, 2008). The World Health Organisation (WHO) drinking water quality guideline is 2mg/L for copper based on observed effect level of 5mg/kg/day in dogs. In United Kingdom, the safe upper level for total daily intake is 10mg/day; at least 1mg/day for non dietary intake (Anonymous 2009 b).

Copper is the functional component in a variety of cuproenzymes (eg. cytochrome oxidase, ascorbic acid oxidase and superoxide dismutase). It plays an important biological role in redox reactions and in scavenging of radicals. United States Recommended Dietary Allowance (USRDA) for dietary intake recommends 0.9mg/day in adult men and women aged more than 19 years. The joint expert committee on Food additives had recommended a provisional maximum tolerable daily intake of 0.5mg/kg/day. For United Kingdom, Department of Health, 1991 had put a dietary reference value of 1.2 mg/day for adults aged 18 years and over (Anonymous 2009 b).

Copper would be subjected to a number of homostatic mechanisms invivo following oral ingestion that reduced the likelihood of toxic sequelae if intake exceeded the normal requirements. The mechanisms involved include bending to metallothionein, absence of significant storage, binding to albumen and trans cuprein and biliary excretion (Anonymous 2009a). The copper residue left after pre treatment with copper acetate was far less than toxic level and hence was under safe level.

5.3. Effect of pre treatments and curing methods on the sensory quality of small cardamom

The effect of pre treatments and curing methods on the physical and chemical qualities of small cardamom were ascertained with the evaluation of sensory qualities. The sensory quality confirms the consumer's requirements as well as acceptance as determined by the sensory attributes. The descriptive

method of analysis of pretreated and cured cardamom involved characters like colour, texture, taste, flavour, appearance and overall acceptability.

5.3.1. Effect of pre treatments and curing methods on appearance of small cardamom

The pre treated cardamom capsules differed significantly in their appearance as revealed by the mean scores. The better appearance was judged for 1% sodium hydroxide treated cardamom capsules (7.25) followed by sodium carbonate (7.16) which was on par with all treatments except cardamom capsules treated with citric acid, naphthalene acetic acid, copper acetate and control. This indicates that cardamom capsules treated with 1% of sodium carbonate, potassium carbonate, magnesium sulphate, sodium hydroxide, sodium bicarbonate, ascorbic acid and polyethylene glycol were better in appearance compared to cardamom capsules treated with 0.1% citric acid, 500 ppm naphthalene acetic acid, copper acetate and control.

The better appearance of these cardamom might be due to the better surface characteristics freedom from defect/damaged surfaces as well as due to the better optical properties such as colour and glossiness. The physical factors such as size, shape, freedom from defect/damaged surface, type and extent of damaged parts and optical properties such as colour, glossiness and transparency and the consistency of the product in different batches or packages were also appearance factors that is indicative of quality (Sivasankar, 2002). Srilakshmi (2010) was also of the opinion that the surface characteristics of food products contribute to appearance.

5.3.2. Effect of pre treatments and curing methods on colour of small cardamom

The pre treated cardamom capsules showed significant variation in the mean values of colour in sensory evaluation. The capsules treated with 1% of sodium carbonate, sodium hydroxide, potassium carbonate and magnesium sulphate showed superior variation in colour and were on par compared to other treatments.

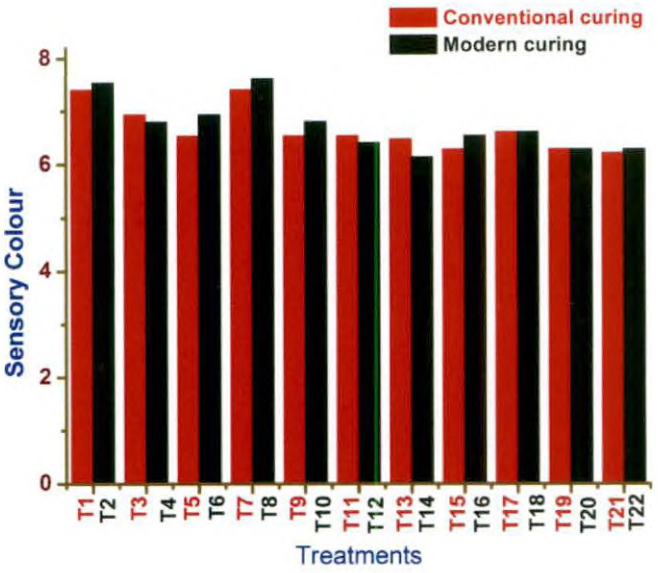

Fig.5. Effect of pre treatments and curing methods on sensory colour of small cardamom

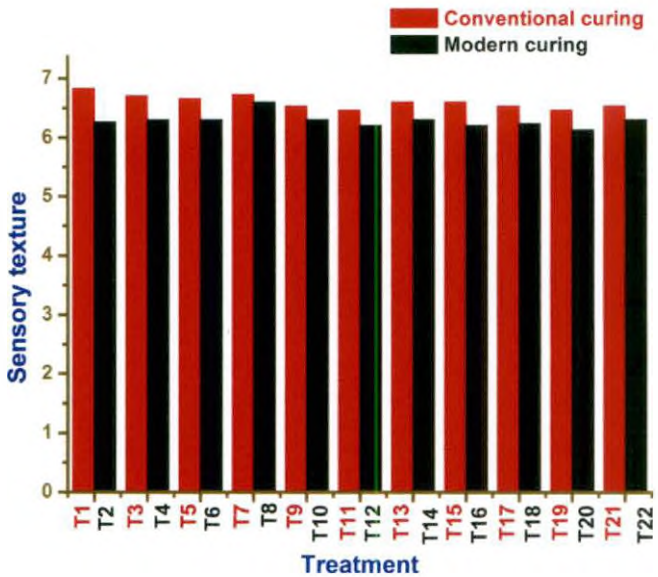

Fig.6. Effect of pre treatments and curing methods on sensory texture of small cardamom

According to Purseglove *et al.* (1981) colour of cardamom fruit did not generally affect the intrinsic organoleptic properties. The better colour in the pre treatments can be attributed to the better chlorophyll retention in sodium carbonate (0.384 mg/g), sodium hydroxide (0.383 mg/g), potassium carbonate (0.378 mg/g) and magnesium sulphate (0.374mg/g). The attractive green colour of cardamom which is due to chlorophyll could be stabilized to a great extent by steeping cardamom in 2% sodium carbonate solution for 10 minutes (Pruthi, 1993). Balakrishnan *et al.* (2002) reported drying of cardamom as one among the unit operation found to influence the green colour of the end product mainly, the total chlorophyll content which is attractive considered to be one of the top most quality characters.

No significant difference was noted in the sensory evaluation of colour with respect to curing methods. There was also no significant difference due to pre treatments curing methods interaction. This means that the colour almost remains similar irrespective of curing methods. This might be because of the similar temperature maintained under conventional and modern curing methods. This fact can be substantiated by the reports of Palaniappan (1982) that the good green colour retention during curing depends on many important factors and one among them being temperature control.

5.3.3. Effect of pre treatments and curing methods on texture of small cardamom

The characters recorded for texture included hardness and crispness. The pre treatment did not make any significant effect on the textural qualities as sensed by the panel of judges. The conventionally cured cardamom was superior in textural qualities compared to modern curing method.

The pre treatments curing methods interaction also did not affect the textural qualities. The calcium treatment found to be most effective in preserving the textural properties of rehydrated dried oyster mushroom as reported by Suhaila and Tok (1994). Beegum (2011) reported superior sensory textural qualities for conventionally retted berries of black pepper.

Katz and Labuza (1981) examined the relationship between water activity (aw) and crispness in a study of popcorn and found a direct relationship between crispness and water activity (aw). The works of de Man (1999) also supported the fact that water activity (aw) and water content as having profound influence on textural properties of foods.

The higher texture score in conventional curing method might be due to superior hardness and crispness in conventional curing method, which might be due to the less moisture content (9.93%) in this method.

5.3.4. Effect of pre treatments and curing methods on taste of small cardamom

The pre treatments, curing methods as well as pre treatments curing methods interaction did not differ significantly in taste as judged by the panel of judges. The characters sensed were sweet and spicy characters which remained almost the same irrespective of treatments and curing methods, which suggests that the pre treatments and curing methods could not influence the sweet and spicy character of cardamom which is mostly a character of cultivar.

5.3.5. Effect of pre treatments and curing methods on flavour of small cardamom

The flavour of cardamom capsules were significantly influenced by the pre treatment and curing methods. The pre treatment curing interaction could not influence the flavour.

Among the pre treatments 1% of sodium hydroxide treated cardamom capsules recorded a mean score of 6.9 followed by 1% of sodium carbonate (6.72) and magnesium sulphate (6.43). These were superior in flavour compared to all other pre treatment. This might to be due to the peculiar chemical nature of the above chemicals in retaining more flavour components. A loss in flavour might have occurred among other pre treatment as well as in control. The volatile oil of cardamom seeds were rich in oxygenated compounds and poor in terpene hydrocarbons (Bastawesy and Mohamed, 2005).

The chemical composition and antioxidant properties of cardamom essential oil was reported by Badei *et al.* (1991). Of the 49 volatile components

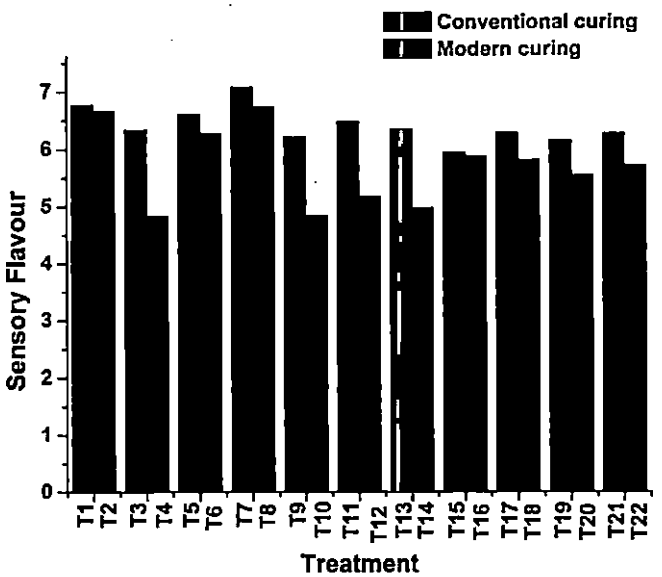

Fig.7. Effect of pre treatments and curing methods on sensory flavour of small cardamom

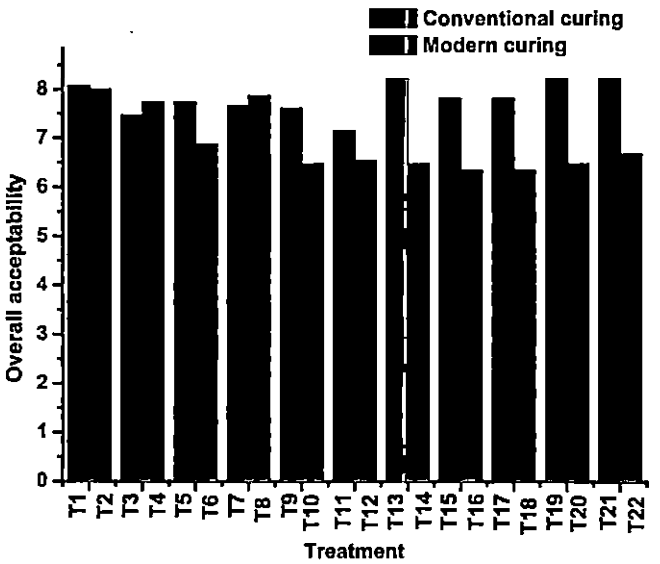

Fig.8. Effect of pre treatments and curing methods on the overall acceptability of small cardamom

found in the essential oil of cardamom, 20 representing 97.14% of the oil where classified; representing nine chemical groups. These were cyclic and aliphatic terpenes, terpene oxides and esters, aromatic hydrocarbons, aliphatic and cyclic terpene alcohols, sesquiterpenes and sesquiterpene and sesquiterpene alcohols.

The composition of cardamom had been studied by various workers (Gopalakrishnan and Narayanan, 1976; Purseglove *et al.*, 1982; Menon, 2000; and Morangia *et al.*, 2004) and the major compounds found were 1, 8 cineole (20-60%) and α-terpinyl acetate (20-55%). The flavour difference in the pretreated capsules might be due to the difference in the different components, which was evident from the gas chromatography-mass spectrometry (GS-MS) analysis.

Among the curing methods better flavour was retained in the conventional curing method, which could be attributed to the more flavour components as well as more alpha-terpinyl acetate under conventional method as revealed by gas chromatography-mass spectrometry analysis.

5.3.6. Effect of pre treatments and curing methods on overall acceptability of small cardamom

The overall acceptability was the same for all the pretreated cardamom capsules as no significant difference was noted among the pre treatment. The overall acceptability between the curing methods represented significant difference. The overall acceptability was superior for the conventional curing method (7.81) compared to modern curing method (6.89). This might be due to the significant difference and flavour of the treated cardamom capsules dried under conventional curing.

FUTURE LINE OF WORK

1. Studying the cellular structure of capsules after the treatment of chemicals.
2. Isolation of different flavour profile of cardamom.
3. Studying the chemical nature and influence of natural materials in effecting green colour and retention of more flavour in cardamom.

Summary

SUMMARY

The experiment entitled "Effect of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardamomum* (L.)Maton" was conducted with the objective of producing good green coloured cardamom having better physical, chemical and sensory qualities. The experiment was conducted at Cardamom Research Station, Pampadumpara during the period 2010-11 and were taken to the Department of Processing Technology, Vellayani for further physical, chemical and sensory analysis. The major findings of the experiment are summarised in this chapter.

The experiment consisted of ten pre treatments, one control and two curing methods. The pre treatments involved 1% of sodium carbonate, potassium carbonate, magnesium sulphate, sodium hydroxide, sodium bicarbonate, copper acetate and 0.1% of citric acid, ascorbic acid, polyethylene glycol and 500 ppm of naphthelene acetic acid. The untreated cardamom capsules were taken as control. The pre treated cardamom capsules and the cardamom capsules taken as control were subjected to drying under two curing methods viz., conventional and modern curing.

The effect of pre treatments under both curing methods on the physical parameters of cardamom capsules such as boldness, bulk density, colour and texture were analyzed. The physical parameters like boldness, bulk density and texture did not show any significant difference with respect to pre treatments, curing methods as well as between pre treatments curing methods interaction. The colour indicated by greenness as well as total colour difference value showed a significant variation with respect to pre treatments. The cardamom capsules treated with 1% of sodium carbonate, sodium hydroxide, potassium carbonate and magnesium sulphate were significantly superior in imparting greenness to cardamom.

The pre treated and cured cardamom were analyzed for the chemical characters. The chemical parameters included moisture content, chlorophyll content in the husk of cardamom capsules, essential oil content, flavour profile of essential oil and the residue of pre treated chemicals in cardamom capsules.

The moisture content, chlorophyll content and essential oil content varied significantly with respect to different pre treatments. Among the pre treatments lower moisture content was recorded for cardamom capsules treated with 1% sodium hydroxide (9.35) and 1% sodium carbonate (9.63). The moisture content in pre treated cardamom capsules showed significant variation with respect to curing methods. The moisture content of pre treated cardamom capsules under conventional curing showed less moisture content compared to modern curing.

Significant variation in chlorophyll content was noted between pre treated cardamom capsules with respect to chlorophyll content of green capsules. The chlorophyll content was superior for cardamom capsules treated with 1% of sodium carbonate and sodium hydroxide. The variation was not significant with respect to curing methods and pre treatments curing methods interaction.

The essential oil content varied significantly with respect to different pre treatments. Higher essential oil content was noted in cardamom capsules treated with 1% of sodium hydroxide, sodium carbonate and magnesium sulphate. The curing methods and the pre treatments curing methods interaction did not influence the essential oil content.

Flavour profile of essential oil of treated small cardamom capsules were analysed using GC-MS (Gas Chromatography Mass Spectrometry) technique. Ninety different chemical compounds had been identified in the essential oil. Further the ten main constituents like 1,8-cineole, α- terpinyl acetate, limonene, linalool, sabinene, trans nerolidol, α-terpineol, linalyl acetate, myrcene,α- pinene had been statistically analyzed to find the influence of pre treatments, curing methods as well as their interactions. Significantly higher percentage of the main compounds like 1, 8-cineole, α- terpinyl acetate, linalool, linalyl acetate were noted in the essential oil obtained from small cardamom capsules treated with 1% sodium hydroxide followed by 1% sodium carbonate. Among the curing methods, small cardamom cured by conventional method yielded higher retention of 1,8-cineole, α- terpinyl acetate, linalool, linalyl acetate, limonene, α-terpineol in the essential oil, compared to modern curing.

The residue of pre treated chemicals on the cardamom capsules after curing were analyzed. The sodium content in the sodium carbonate, sodium hydroxide and sodium bicarbonate treated cardamom capsules significantly varied from the sodium content of untreated cardamom capsules (control). Significantly higher sodium content was noted in the cardamom capsules treated with sodium carbonate followed by sodium hydroxide and sodium bicarbonate. The sodium content of cardamom capsules also significantly differed with respect to curing methods as well as between pre treatments – curing methods interaction. The sodium content noted under modern curing was significantly superior compared to conventional curing.

The potassium content in the pre treated cardamom capsules varied significantly from the control. The potassium content of cardamom capsules dried in the modern curing varied significantly from the conventional curing with more residue of potassium under modern curing. The pre-treatments curing methods interaction effect was not significant with respect to residue of potassium.

The magnesium content in the cardamom capsules treated with magnesium sulphate revealed significant variation compared to untreated cardamom capsules. The variation was not significant with respect to the magnesium content of cardamom capsules dried under different curing methods and between pre treatments curing methods interaction.

The ascorbic acid content in the cardamom capsules treated with ascorbic acid revealed significant variation compared to control. However the variation was not significant with respect to curing methods and pre treatments curing methods interaction.

The copper residue in the cardamom capsules treated with copper acetate showed a significant variation in residue compared to control. No significant variation in the residue level of copper was noticed in curing methods. The variation was insignificant with respect to interaction of pre treatments and curing methods.

The residue of citric acid in the cardamom capsules treated with citric acid recorded a significant level compared to control. The significant variation

was noted between curing methods also. The interaction effect due to pre treatments and curing methods was also significant considering the residue of citric acid.

The cardamom capsules treated with naphthalene acetic acid showed a significant level of residue of naphthelene acetic acid (NAA) compared to control which was above the reported MRL level for apple, pear, quince and pineapple. However among curing methods and pre treatments curing methods interaction the effect was not significant.

Significant level of residue was noticed in polyethylene glycol (PEG) with respect to its residue compared to control. The residue level was significant under curing methods as well as between interaction of pre treatments and curing methods.

The effect of pre treatments and curing methods on the sensory parameters of cardamom capsules were judged by a panel of judges. The sensory qualities scored included qualities like colour, flavour, texture, taste, appearance and overall acceptability.

The organoleptic qualities for colour, flavour, texture, appearance and overall acceptability showed significant variation among pre treatments. Significant variation was noticed in flavour, texture and overall acceptability in curing methods adopted also. The pre treatments curing methods interaction was significant with respect to overall acceptability alone. Among the various pre treatments tried superior colour, flavour, texture and appearance was noticed for cardamom capsules treated with 1% of sodium hydroxide and sodium carbonate.

Considering the physical, chemical and sensory qualities analyzed for the ten pre treatments tried and control, the best pre-treatment turned out to be immersing fresh small cardamom capsules in 1% sodium hydroxide and 1% sodium carbonate for two minutes. Among the curing methods, conventionally cured cardamom capsules showed better retention of flavour compounds like 1,8-cineole, α-terpinyl acetate, limonene, linalool, α- terpineol and linalyl acetate. The moisture retention content was less under conventional method compared to modern method of curing. Among the sensory parameters better flavour and

texture was obtained from cardamom capsules cured under conventional curing. However the instrumental measurement of colour and texture could not find any significant difference between conventional and modern curing. The residue of sodium in the 1% sodium hydroxide and 1% sodium carbonate treated small cardamom showed only moderate value. Hence the present investigation suggests pre treating small cardamom capsules with 1% sodium hydroxide or 1% sodium carbonate under conventional curing for better quality parameters.

CONCLUSION

The cardamom capsules treated with 1% sodium hydroxide and 1% sodium carbonate for two minutes produced good quality green capsules. The green colour retention under conventional and modern curing was almost similar but better flavour profile in essential oil of small cardamom was observed under conventional curing method compared to modern curing method. The sensory flavour and texture characters scored were superior under conventionally cured samples. However the instrumental measurement for colour and texture could not measure any difference between conventional and modern method of curing. Hence treating the cardamom capsules with 1% sodium hydroxide or 1% sodium carbonate for two minutes followed by conventional curing can be suggested for better quality small cardamom.

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Abstract

EFFECT OF PRE TREATMENTS AND CURING METHODS ON THE QUALITY CHARACTERS OF PROCESSED CARDAMOM

(*Elettaria cardamomum* (L.) Maton)

SONIA, V.

(2010-12-107)

ABSTRACT

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(Processing Technology)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PROCESSING TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2012

ABSTRACT

The research on "Effect of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardmomum* (L.)Maton" was undertaken at Department of Processing Technology, College of Agriculture, Vellayani with the objective of developing a pre treatment for cardamom which can retain good quality green colour having better flavour, texture, appearance and acceptability.

The experiment was done at Cardamom Research Station Pampadumpara and the analysis was carried out at Department of Processing Technology, College of Agriculture, Vellayani. The experiment was laid out in factorial completely randomised design with three replications. The cardamom capsules were treated with different chemicals and dried under two curing methods. Pre treatments consisted of 1% of sodium carbonate, potassium carbonate, sodium hydroxide, sodium bicarbonate, magnesium sulphate, copper acetate and 0.1% of ascorbic acid, citric acid, polyethylene glycol and 500 ppm of naphthalene acetic acid. An untreated control was also included in the experiment. These cardamom capsules were then dried under conventional and modern drier and evaluated for physical, chemical and sensory qualities.

The effect of pre treatments and curing methods on physical qualities of cardamom was evaluated. The boldness, bulk density and instrumental measurement of texture were not affected by the pre treatments as well as by curing methods. The greenness and total colour difference were influenced by the pre treatments. The cardamom capsules treated with 1% sodium hydroxide and sodium carbonate were superior in imparting greenness to the capsule colour. The result of total colour difference also substantiates this.

The chemical parameters such as moisture, chlorophyll and essential oil content were significantly influenced by different pre treatments. The curing methods did not influence the chlorophyll and essential oil content of cardamom

capsules. Flavour profiles of essential oil content of small cardamom were analysed using Gas Chromatography Mass Spectrometry. The major ten chemical components (1,8-cineole, α -terpinyl acetate, limonene, linalool, sabinene, trans nerolidol, α-terpineol, linalyl acetate, myrcene, α- pinene) present in essential oil of small cardamom were statistically analyzed. Cardamom capsules treated with 1% sodium hydroxide and 1% sodium carbonate showed better flavour profile with respect to α-terpinyl acetate, linalool and linalyl acetate in essential oil of small cardamom compared to other chemical pre treatments. The moderate content of 1,8-cineole with higher α -terpinyl acetate, linalool and linalyl acetate might have resulted in better flavour as noticed by sensory evaluation of cardamom capsules pre treated with 1% sodium hydroxide and 1% sodium carbonate. Conventionally cured cardamom capsules showed better retention of flavour compared to modern curing method with respect to 1,8-cineole, α -terpinyl acetate, limonene, linalool, α-terpineol and linalyl acetate. The pre treated cardamom capsules were analysed to find the residue content of the pre treated chemicals. The residue of sodium, potassium, magnesium, ascorbic acid and citric acid analysed were below the toxic level and would not cause any harm since they are needed in trace amounts in human body. The presence of heavy metal copper was also below the maximum residual level. The naphthalene acetic acid (NAA) content was a bit slightly above the normal level recommended for apple, pear, quince and pineapple. A significant level of residue of polyethylene glycol (PEG) was noted compared to control.

The sensory tests carried out revealed better colour, flavour, texture, appearance and overall acceptability for the cardamom capsules treated with 1% of sodium carbonate and sodium hydroxide compared to other pre treated capsules as well as control. The flavour, texture and overall acceptability was superior in cardamom capsules dried under conventional curing compared to modern curing.

The study concludes that the pre treating cardamom capsules at 1% sodium carbonate or 1% sodium hydroxide for two minutes gave better colour, flavour

and overall good acceptability of cardamom. Both curing methods were ideal with regard to the general colour and texture as indicated by instrumental measurements. However the flavour profile of essential oil of small cardamom and sensory qualities were scored in favour of conventional curing method.

Appendices

APPENDIX-I

KERALA AGRICULTURAL UNIVERSITY

COLLEGE Of AGRICULTURE, VELLAYANI

Department of Processing Technology

Title of Thesis: Effect Of pre treatments and curing methods on the quality characters of processed cardamom (*Elettaria cardamomum* (L.) Maton)

Name of student: SONIA.V (2010-12-107)

SCORE CARD FOR ASSESSING QUALITY PARAMETERS OF SMALL CARDAMOM

Sl.no	CRITERIA	SAMPLES										
		1	2	3	4	5	6	7	8	9	10	11
1	**COLOUR**											
2	**FLAVOUR**											
	Cardamom flavor											
	Off flavour if any											
3	**TEXTURE**											
	Crispness											
	Hardness											
4	**TASTE**											
	Sweet											
	Spicy											
5	**APPEARANCE**											
	Boldness											
	Splitting if any											
	Any Other Remarks											

Score

Like Extremely	-9
Like Very Much	-8
Like Moderately	-7
Like Slightly	-6
Neither Like Nor Dislike	-5
Dislike Slightly	-4
Dislike Moderately	-3
Dislike Very Much	-2
Dislike Extremely	-1

Name:

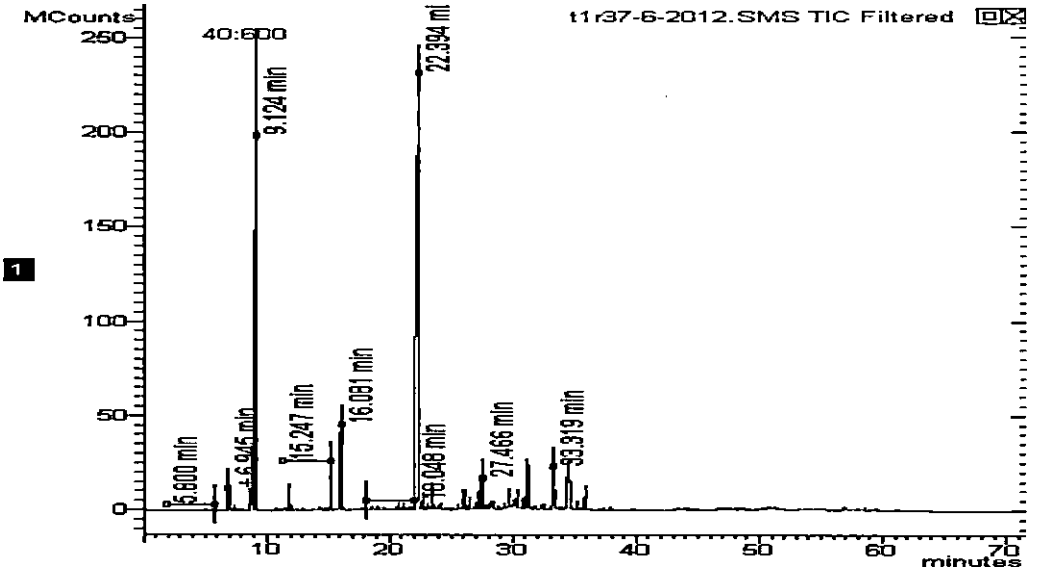
Date :

Signature:

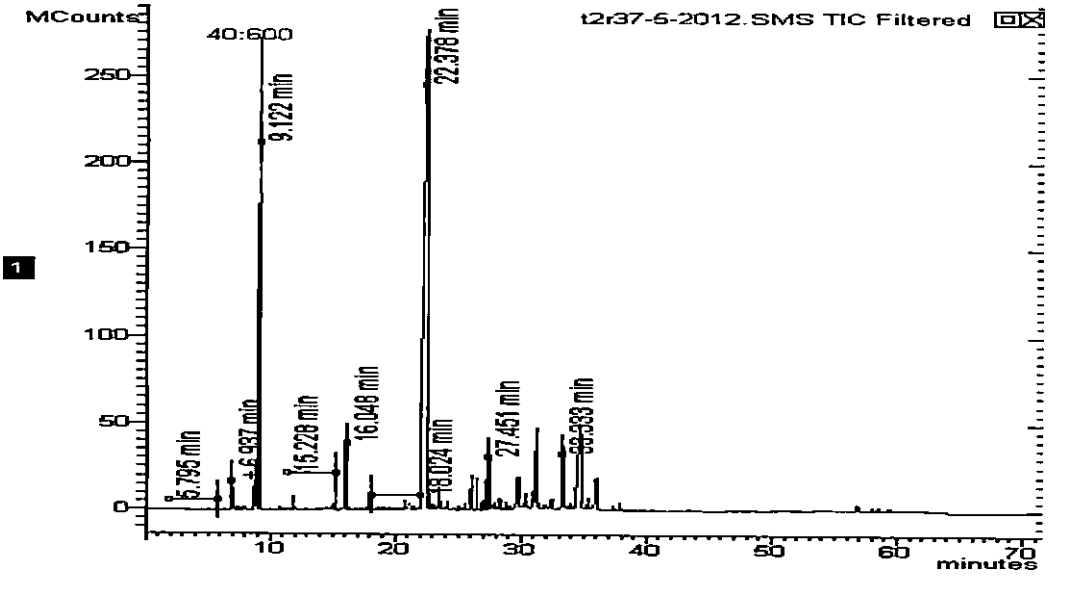
APPENDIX II

Chromatogram of essential oil of small cardamom samples pre treated with different chemicals

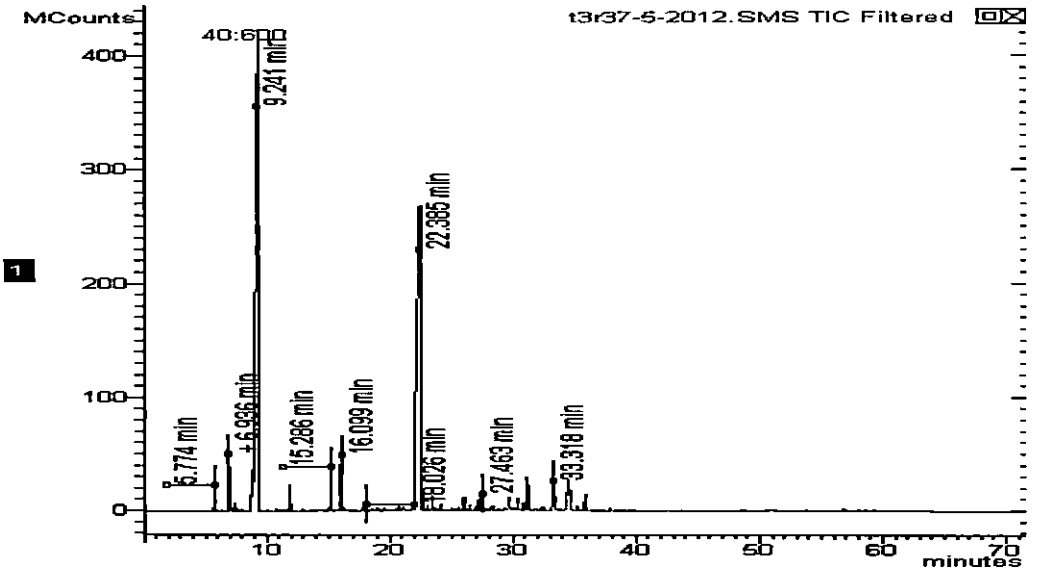
1. Chromatogram of essential oil of small cardamom samples pre treated with sodium carbonate (1%) under conventional curing



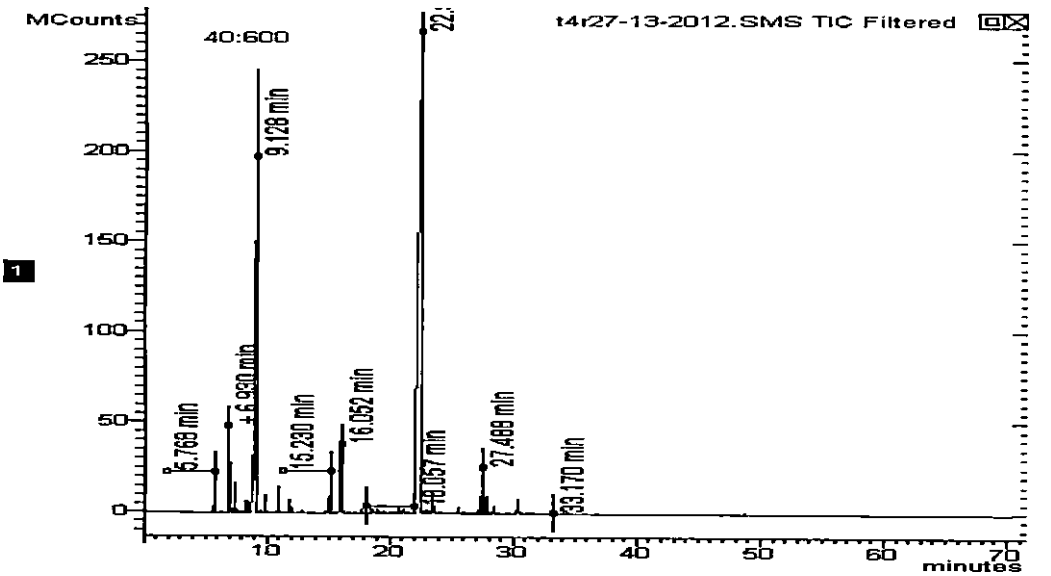
2. Chromatogram of essential oil of small cardamom samples pre treated with sodium carbonate (1%) under modern curing



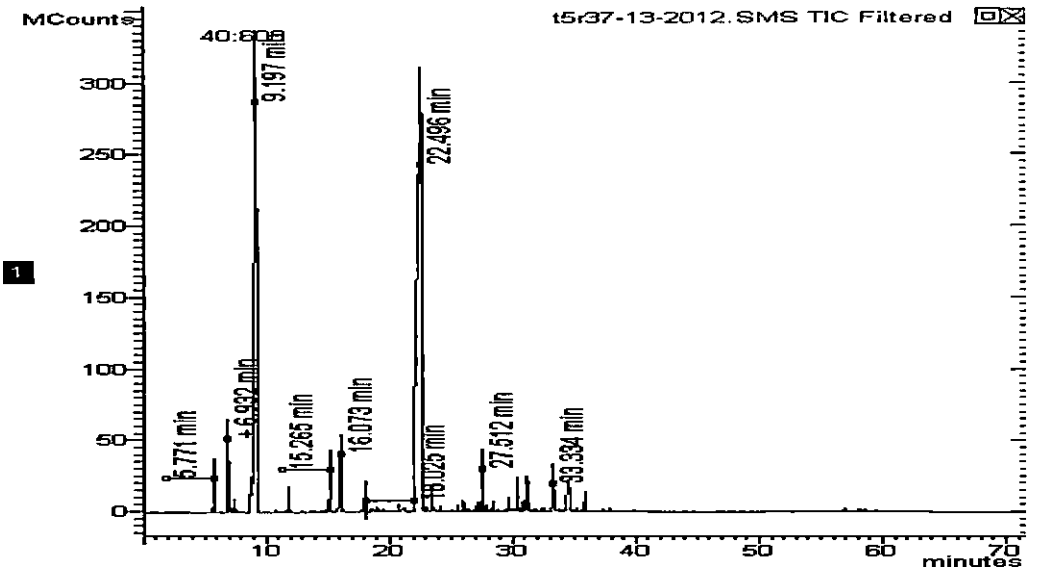
3. Chromatogram of essential oil of small cardamom samples pre treated with potassium carbonate (1%) under conventional curing



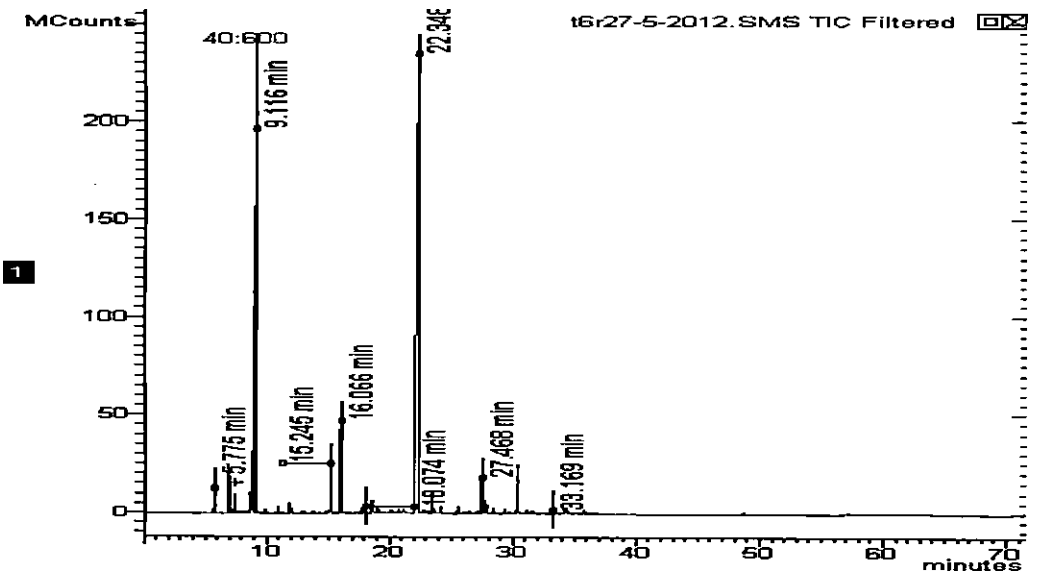
4. Chromatogram of essential oil of small cardamom samples pre treated with potassium carbonate(1%) under modern curing



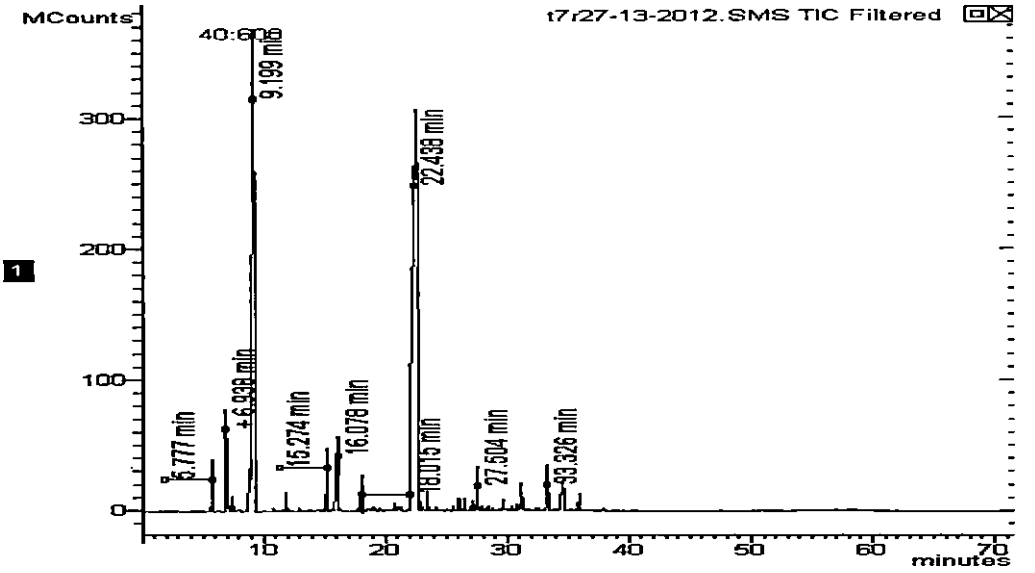
5. Chromatogram of essential oil of small cardamom samples pre treated with magnesium sulphate (1%) under conventional curing



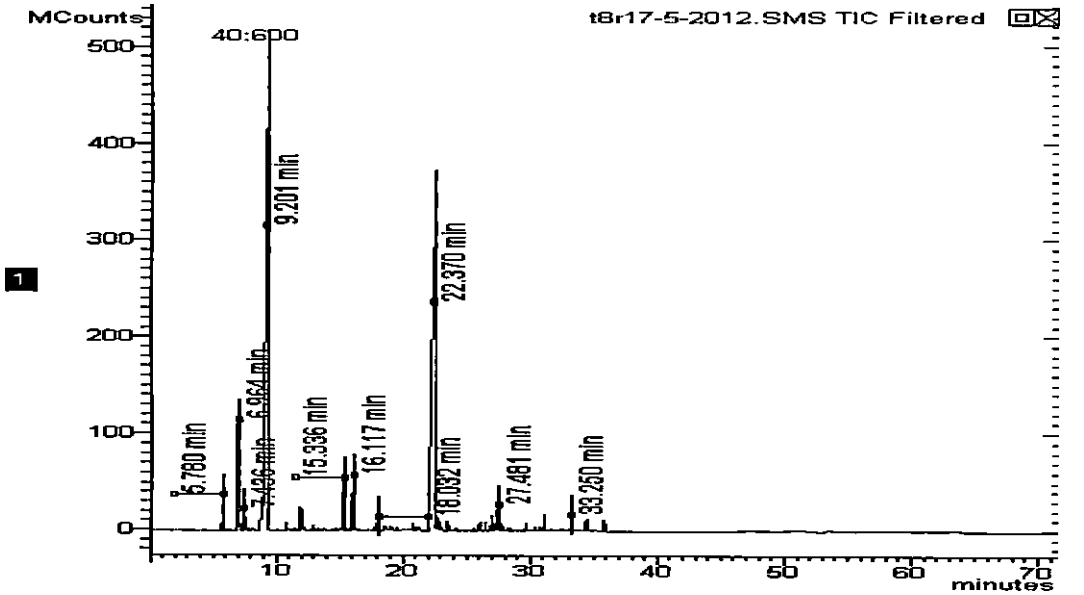
6. Chromatogram of essential oil of small cardamom samples pre treated with magnesium sulphate (1%) under modern curing



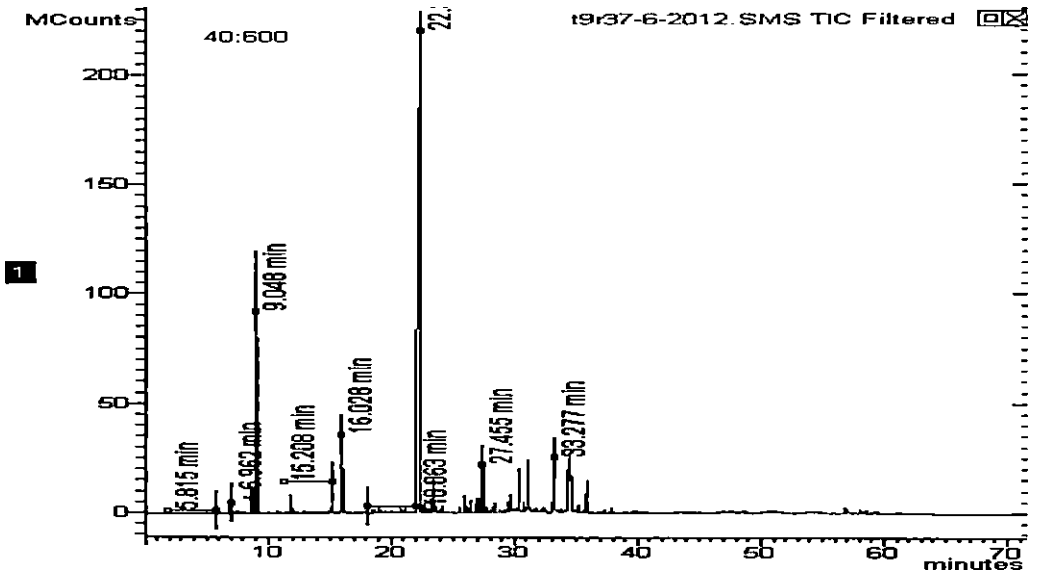
7. **Chromatogram of essential oil of small cardamom samples pre treated with sodium hydroxide (1%) under conventional curing**



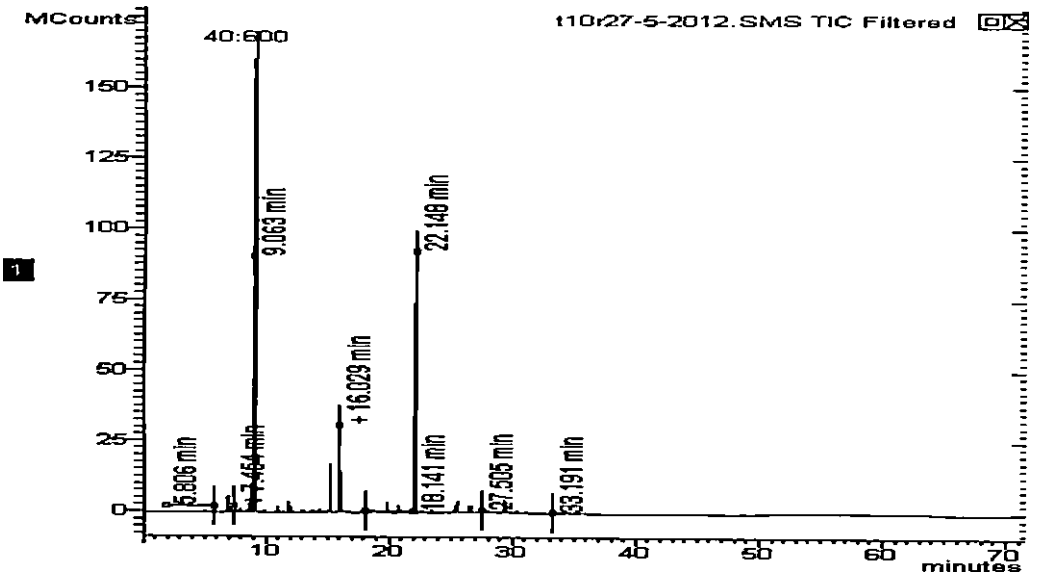
8. **Chromatogram of essential oil of small cardamom samples pre treated with sodium hydroxide (1%) under modern curing**



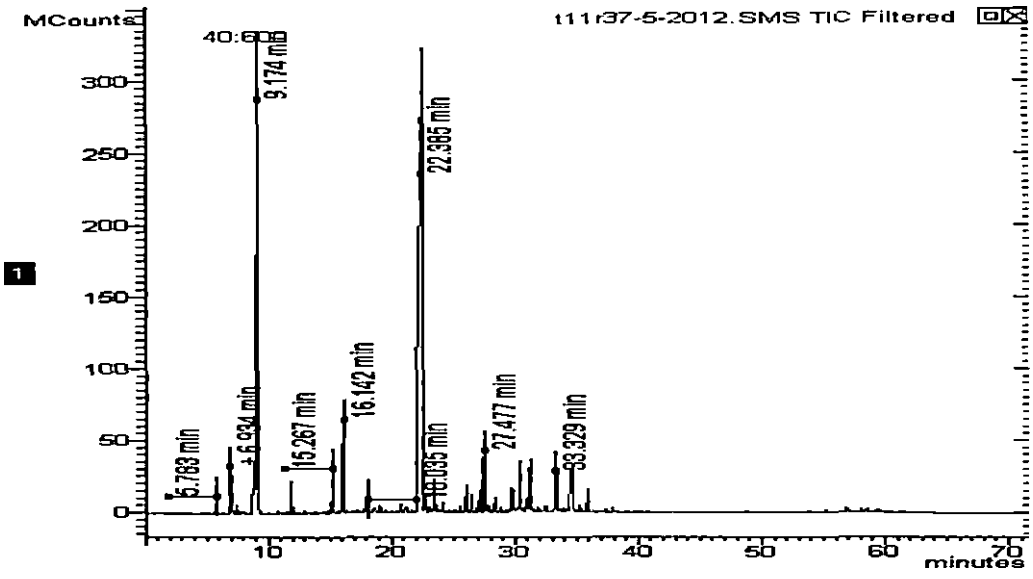
9. Chromatogram of essential oil of small cardamom samples pre treated with sodium bicarbonate (1%) under conventional curing



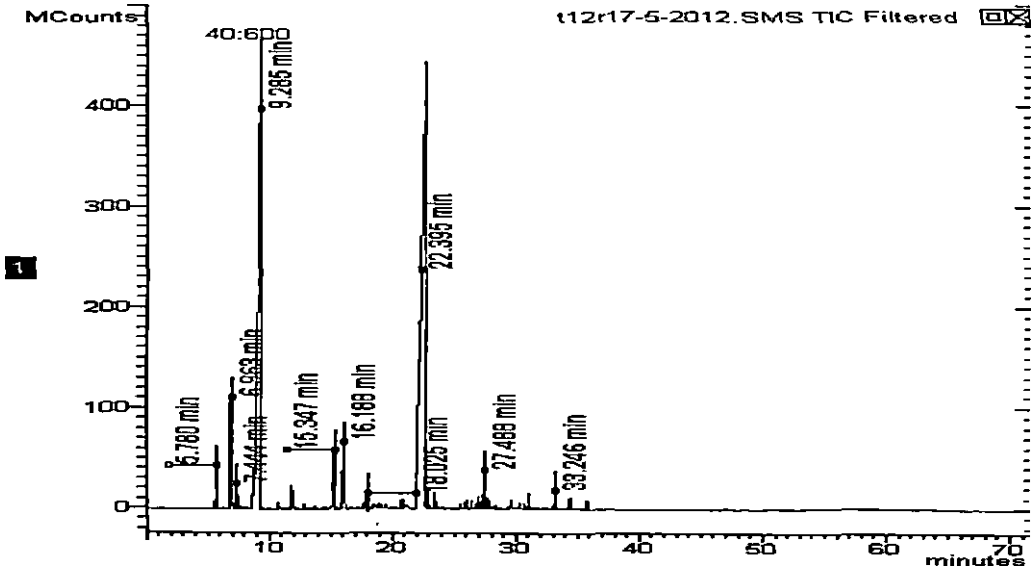
10. Chromatogram of essential oil of small cardamom samples pre treated with sodium bicarbonate (1%) under modern curing



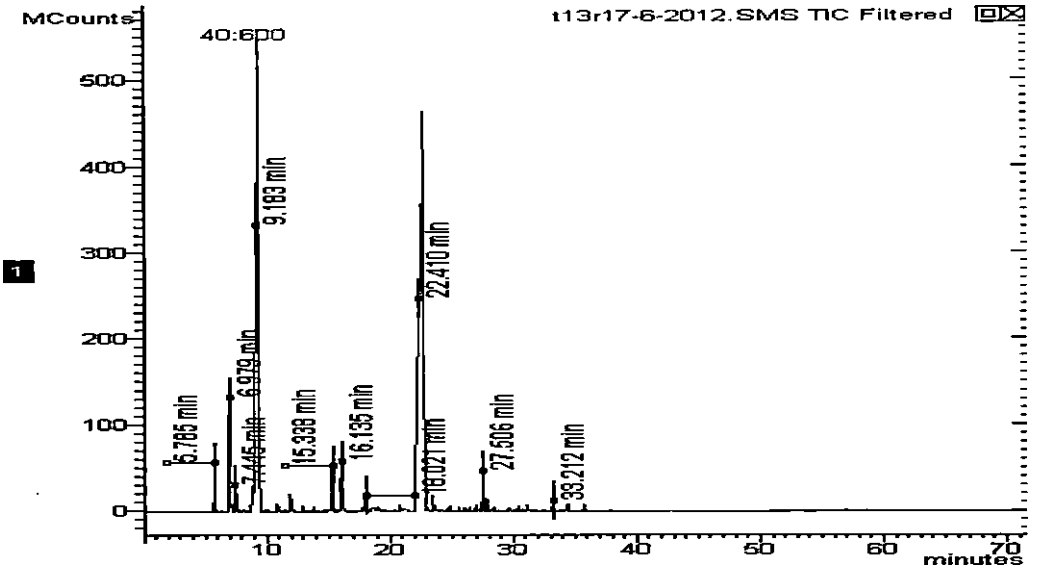
11. Chromatogram of essential oil of small cardamom samples pre treated with ascorbic acid (0.1%) under conventional curing



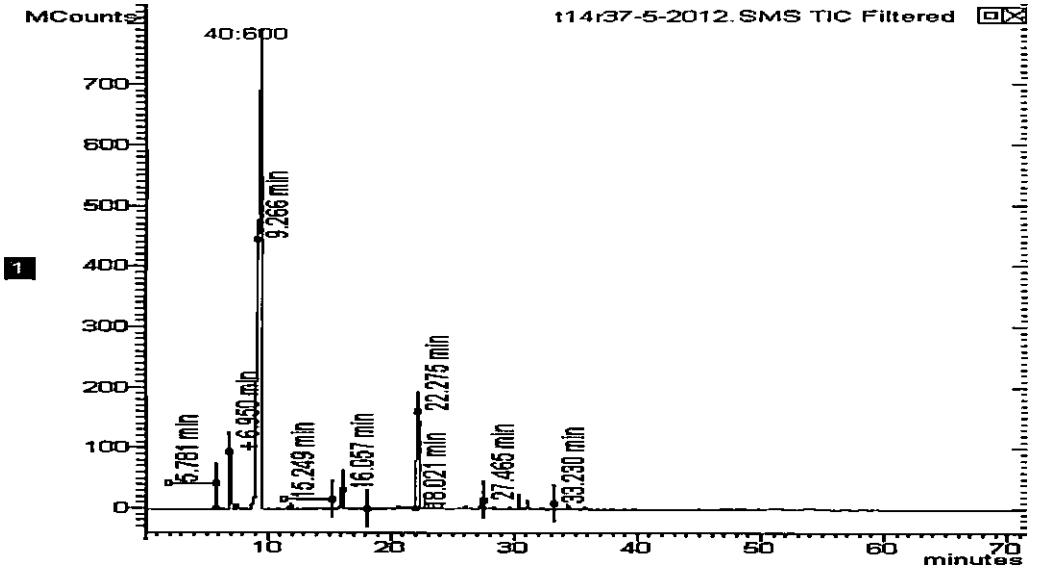
12. Chromatogram of essential oil of small cardamom samples pre treated with ascorbic acid (0.1%) under modern curing



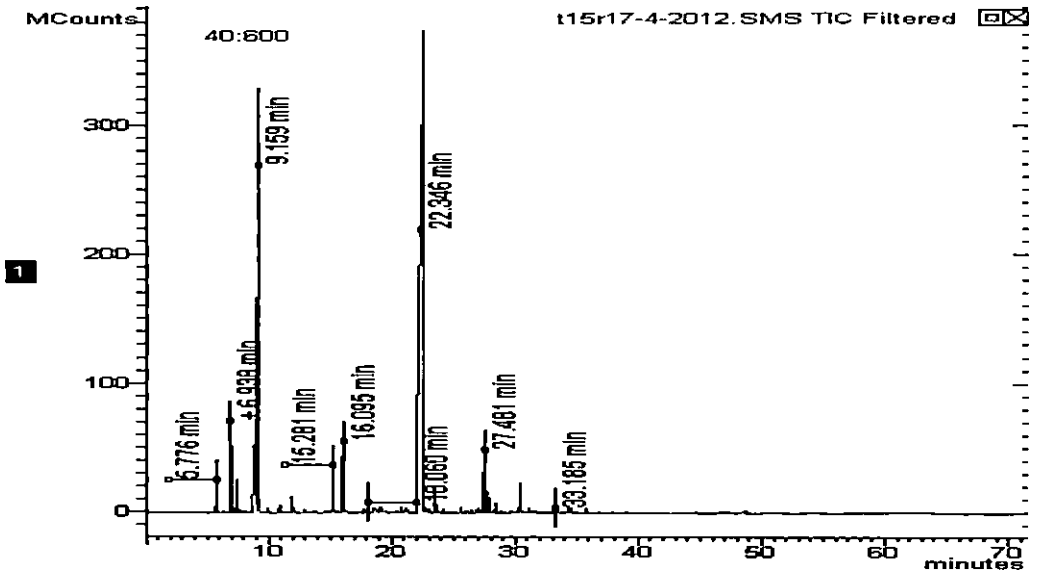
13. Chromatogram of essential oil of small cardamom samples pre treated with citric acid (0.1%) under conventional curing



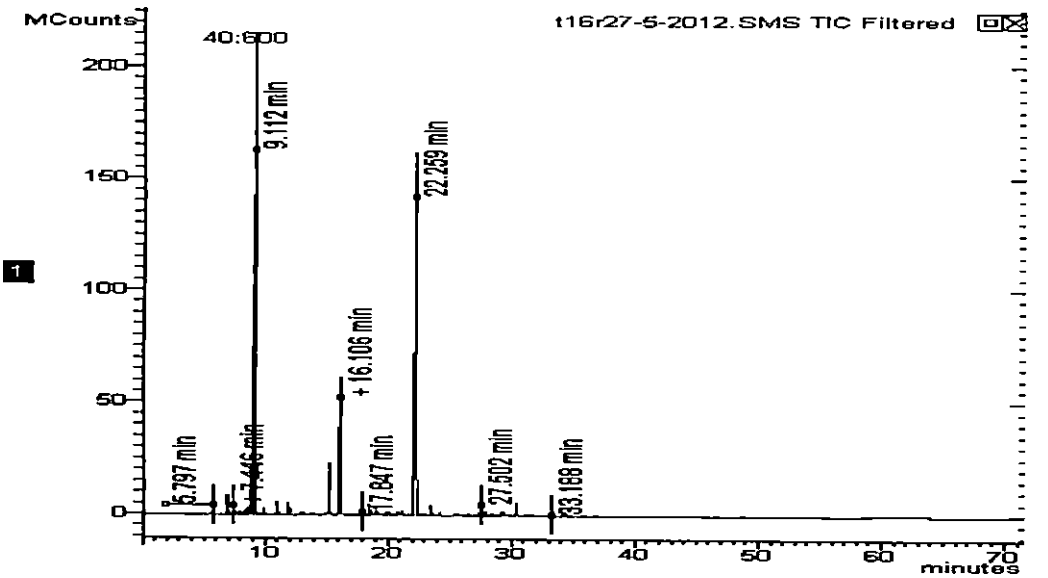
14. Chromatogram of essential oil of small cardamom samples pre treated with citric acid (0.1%) under modern curing



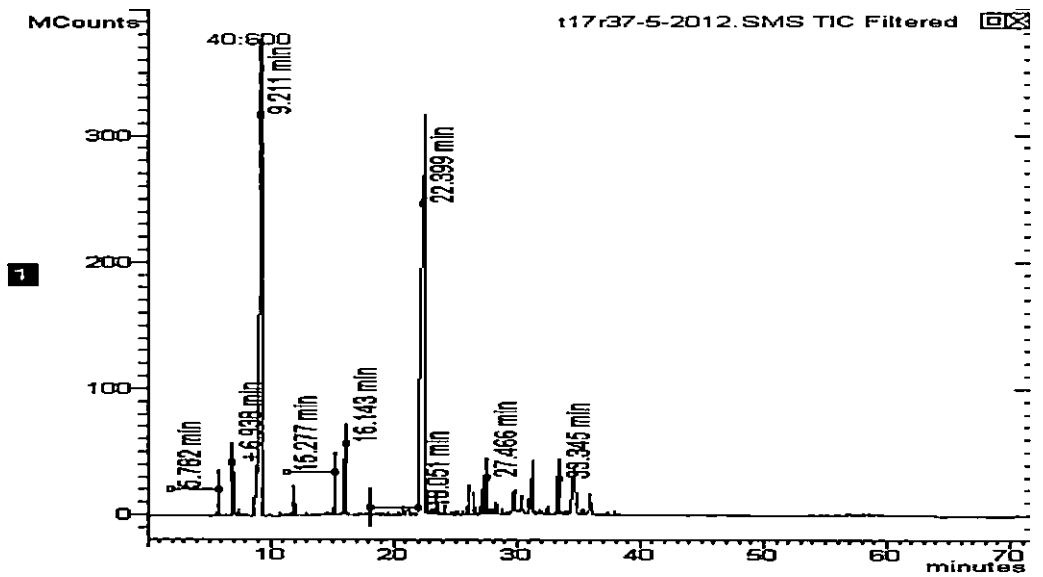
15. Chromatogram of essential oil of small cardamom samples pre treated with polyethylene glycol (0.1%) under conventional curing



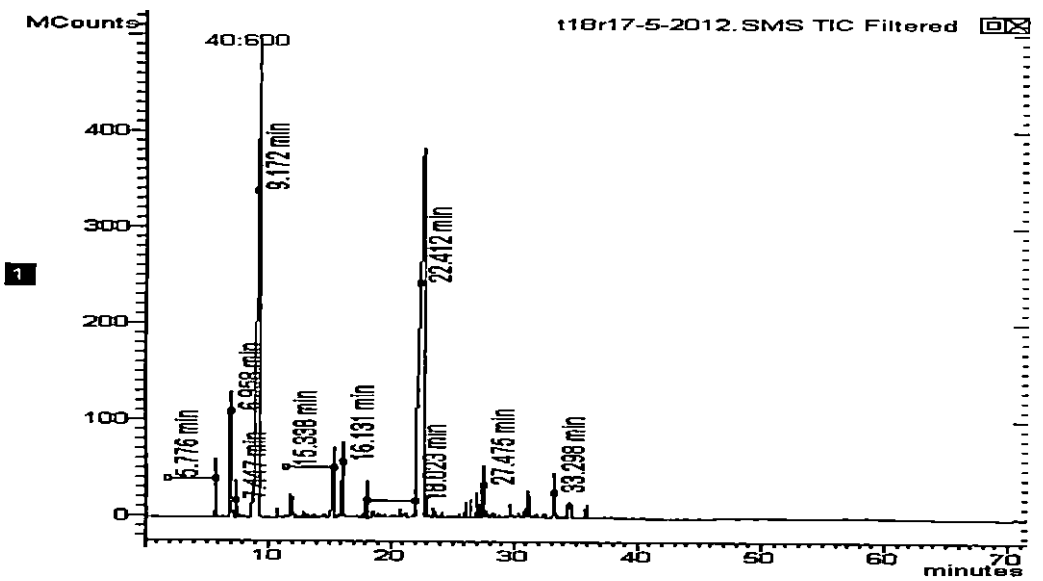
16. Chromatogram of essential oil of small cardamom samples pre treated with polyethylene glycol (0.1%) under modern curing



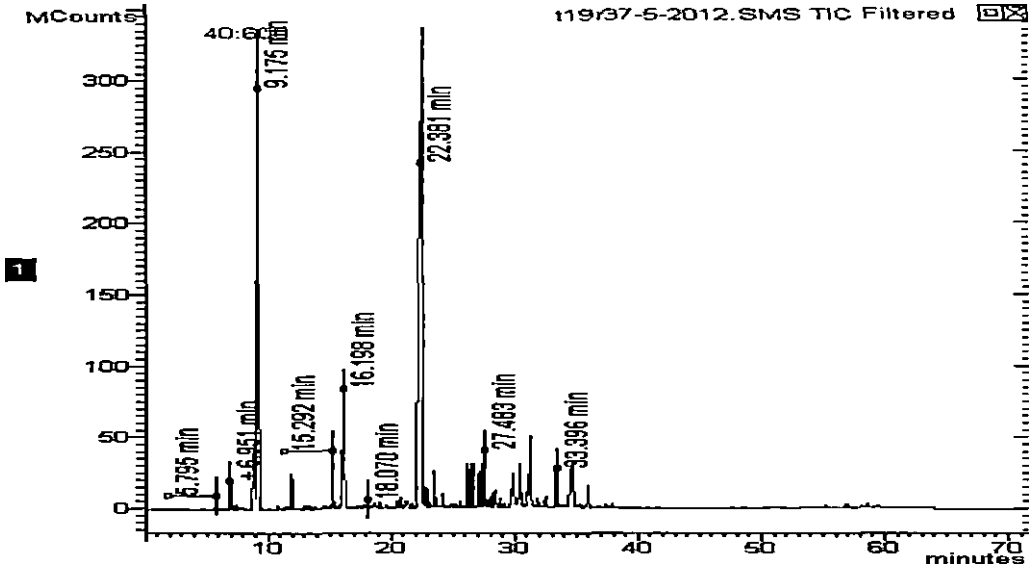
17. Chromatogram of essential oil of small cardamom samples pre treated with naphthalene acetic acid (500 ppm) under conventional curing



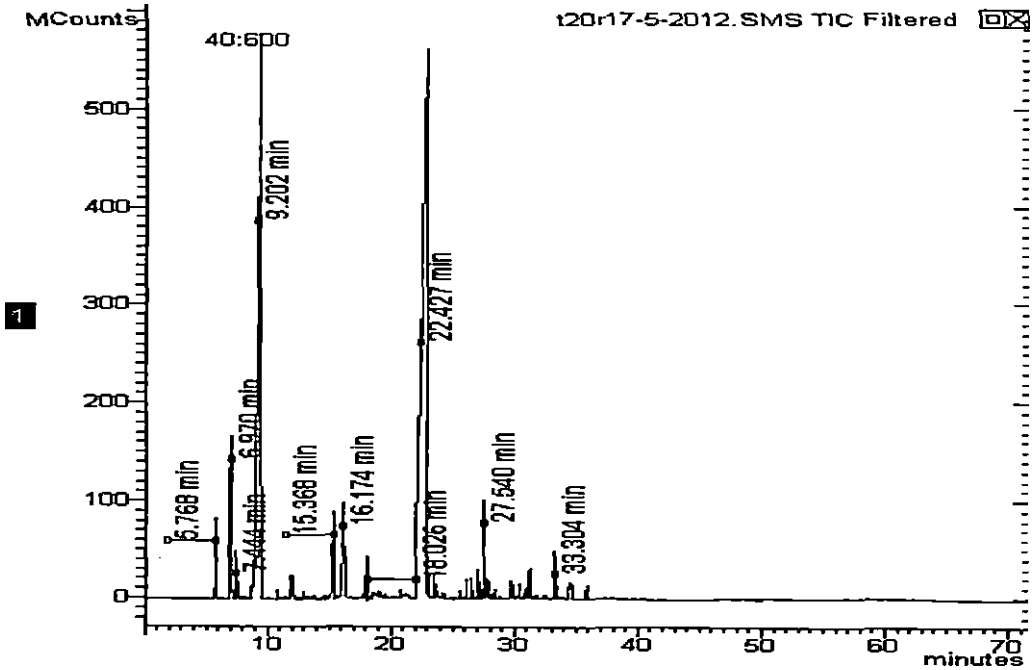
18. Chromatogram of essential oil of small cardamom samples pre treated with naphthalene acetic acid (500 ppm) under modern curing



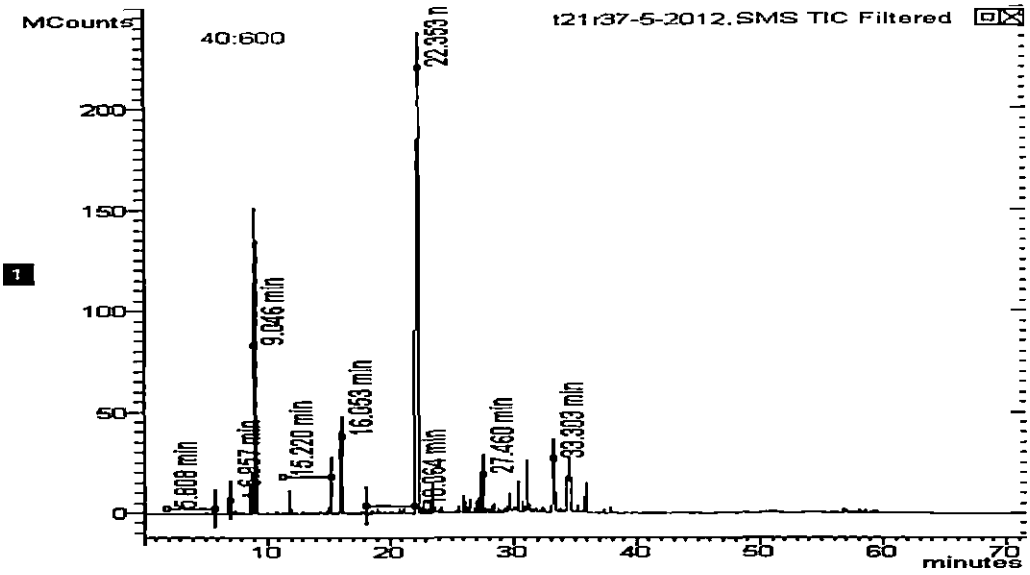
19. Chromatogram of essential oil of small cardamom samples pre treated with copper acetate (1%) under conventional curing



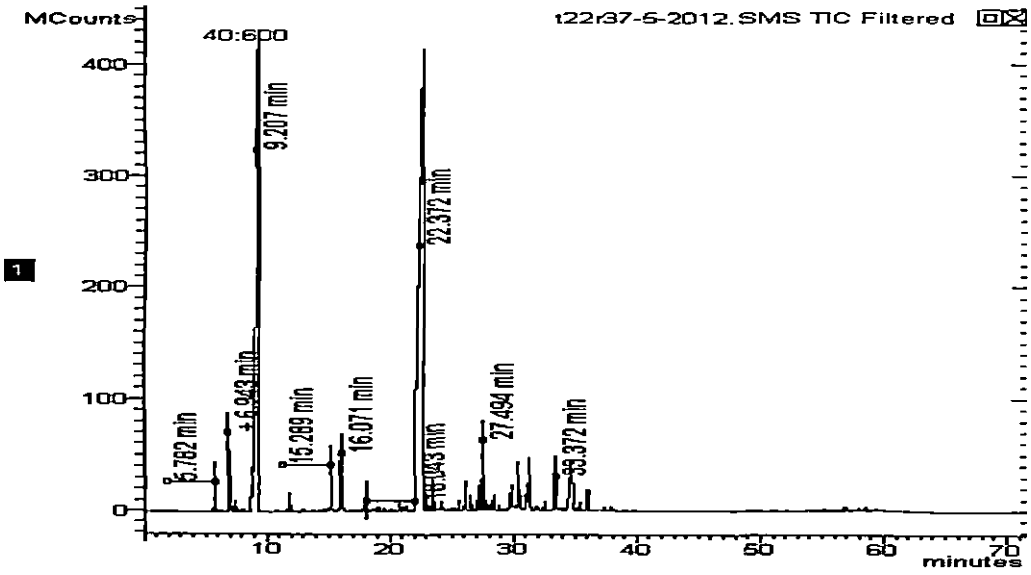
20. Chromatogram of essential oil of small cardamom samples pre treated with copper acetate (1%) under modern curing



21. Chromatogram of essential oil of small cardamom samples pre treated as control under conventional curing



22. Chromatogram of essential oil of small cardamom samples pre treated as control under modern curing



Chromatogram of essential oil of small cardamom samples pre treated and cured under conventional and modern method showed the following chemical compounds. Though more than 150 peaks were identified, the peaks of major ten compounds were represented here. Each particular compound corresponds to particular period of retention time in all the treatments. If a compound shows identical mass spectrum and retention time with a known compound then, they are considered identical. The major ten compounds identified in a range of retention time were listed below (Table 6).

Table. 6. Compounds present in chromatogram of treated small cardamom samples

Sl.No	Range of retention time	Name of compound
1	5.7 - 5.82	Limonene
2	6.93 - 6.97	Sabinene
3	7.42 - 7.46	Myrcene
4	9.05 - 9.29	α- terpinyl acetate
5	15.22 - 15.41	α –terpineol
6	16.03 -16.23	Linalool
7	18.02 - 18.14	α –pinene
8	22.26 - 22.51	1,8-cineole
9	27.45 - 27.54	trans nerolidol
10	33.17 – 33.40	linalyl acetate