QUALITY AND SHELF LIFE OF NAGA KING CHILLI (*Capsicum chinense* Jacq.) AS INFLUENCED BY MATURITY STAGES AND POST HARVEST TREATMENTS

Thesis

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of

Doctor of Philosophy

in

HORTICULTURE (Vegetable Science)

by

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CERTIFICATE – I

This is to certify that the thesis entitled "**Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments**"submitted to Nagaland University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the discipline of Horticulture (Vegetable Science) is the record of research work carried out by Ms.Kerimenla Registration No. 838/2019 under my personal supervision and guidance.

The results of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (Vegetable Science)

This is to certify that the thesis entitled **"Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments"** submitted by Ms.Kerimenla Admission No.198/15 Registration No. 838/2019 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award degree of Doctor of Philosophy in Horticulture (Vegetable Science) has been examined and approved by the Advisory Board and External examiner on **30.11.2020**

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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STUDENT'S DECLARATION

I, Kerimenla, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree to any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Horticulture (Vegetable Science).

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

A.O.A.C.	Official method of analysis
ASTA	American Spice Trade Association
Approx.	Approximate
CD	Critical Difference
DAS	Days After Storage
et al.	et al ia (and others)
etc.	Etcetra
Fig.	Figure
g	Gram
i.e	id est (in other words)
mg	Milligram
ml	Millilitre
%	Percentage
PE	Poly Ethylene
PLW	Physiological Loss in Weight
ppm	Parts per million
SHU	Scoville Heat Units
TSS	Total Soluble Solids
Viz.	Videlicet (Namely)

CHAPTER-1

INTRODUCTION

INTRODUCTION

Chilli is one of the major cash crops in India, grown both for domestic and international markets. Different cultivars of chilli are being grown for vegetables, spices, pickles, condiments etc. It is mainly used for its pungency and colouring properties. India is the largest producer and consumer of chilli among the major producer of the world. India contributes about 25% to the total world production and remain aṭ the first position in terms of international trade by exporting different forms of hot peppers like chilli powder, dried chilli, pickled chillies and chilli oleoresins.

Fruit in the genus of *Capsicum* have been classified as non-climacteric (Lurie *et al*., 1986; Biles *et al*., 1993), but the hot chilli cv. 'Chooraehong' (*Capsicum frutescens*) was reported as climacteric (Gross *et al*., 1986). Chilli pepper (*Capsicum* sp.), is valued around the world for its colour, flavor, spice and nutritional value (Berke *et al*., 2004). It is a rich source of vitamin C (Marin *et al*., 2004) and pro-vitamin A. it is a good source of most B vitamins, particularly B6, and also high in potassium, magnesium and iron (Acedo, 2006). The two chemical groups of greatest interest in chilli are the capsaicinoids and the carotenoids. The capsaicinoids are alkaloids that give hot chilli peppers their characteristic pungency or hot feiry taste. The rich supply of carotenoids contributes to chilli peppers nutritional value because they serve as pro-vitamin A, which after digestion is converted into vitamin A (retinol) and gives the characteristic bright colour to the dried fruits (Homero-Mendez *et al*., 2002). Chilli fruits are primarily consumed as fresh vegetable or as spice. Chilli extracts are also used in pharmaceutical and cosmetic products. Introduced from Tropical and South America in the 17th century, chillies are now grown in almost all parts of India occupying an area of 28.7 lakh ha with an estimated production of 34.06 lakh Tonnes (NHB, 2017). Important chilli growing states in India are Andhra Pradesh, Maharashtra, Karnataka, Tamilnadu, Madhya Pradesh and Orissa.

Chilli has made quite an impression as a cash crop in North Eastern states due to its multiferous uses. This region has been blessed with diverse genetic resources of chilli with wider adaptability. Many species of Capsicum are found scattered here which primarily include *Capsicum frutescens*, *Capsicum chinense* and *Capsicum annuum*. Among these, Bird's Eye Chilli (*Capsicum frutescens*) is in demand in International market for its high pungent fruits (Baruah and Baruah, 2004). Chilli is valued for their sensory attributes of colour, pungency and flavor (Pino *et al*., 2007). The Amazon is an important centre of diversity for chilli particularly of the genus *Capsicum chinense* Jacq., although over the last decade, the degradation of the genus due to anthropic pressure has been intense.

Naga king chilli, botanically known as *Capsicum chinense* Jacq., is extensively grown in the north-eastern region of India, predominantly in the states of Assam, Nagaland and Manipur. It belongs to the family solanaceae and its chromosome number is 2n=24. The plant is a sub shrub with multiple stems. It may be 45-120 cm tall with green coloured stem and leaves. The length of leaf may be as high as 10.65-14.25 cm with width 5.4-7.5 cm. The colour of flower is yellowish green with pale blue anther. Flowering occurs 120-130 days after transplanting and fruiting takes place after 15-20 days of flowering. The fruit is a berry, consisting of a pericarp, placenta, seed and dry cavity. The shape of the fruit is sub-conical to conical with length of 5.95-8.54cm and width of 2.50 – 2.95 cm. A mature fruit may weigh up to 6.95-8.97 g and contains about 19.22-34.15 number of light brown seeds. It is native to North- Eastern India more particular to Nagaland (Bhagowati and Changkija, 2009).

In Nagaland, it is called *Naga mircha*, *Raja mircha* (king of chilli) or Naga king chilli, in Assam, it is called as *Bhut jolokia* (*Bhut* means Ghost, *jolokia* means chilli in Assamese which is probably due to its ghostly bite), *Bih jolokia* (poison chilli), Naga king chilli (due to acute hotness representing the aggressive temperature of the warriors of neighbouring Naga community). In

Manipur, it is known as *Oo-morok* (Oo means tree and morok means chilli in manipuri which is due to its perennial nature of growing habit like a tree). However, the name was most probably derived from the ‘Bhutias’ who brought and traded this commodity during the ancient times. The Naga king chilli is a traditional food item of the Naga people. It is eaten either raw or cooked and can hardly be termed as spice. It is typically thick fleshed, three or four lobbed. It is a rich source of vitamin C, A and superior to tomato in this respect. The Nagaland Government had in 1999 passed the Nagaland Geographical Indication of Goods (Registration and Protection) Act, to provide safety net to Naga farmers in the cultivation of the king chilli and has obtained the GI rights for this crop in 2008. In 2007, Naga king chilli was recognized in the Guinness book of records as the world’s hottest chilli with 1,041,427 Scoville Heat Units by HPLC. However, the *Bhut jolokia* was shortly superseded by the infinity chilli in early 2011, followed by the Naga Viper, then later the Trinidad Moruga Scorpion in 2012, and finally the "Carolina Reaper" on August 7, 2013 (Roy, 2016).

The *Bhut jolokia* chilli has been cultivated in a traditional manner since time immemorial and there exists a considerable amount of genetic variability among the landraces. It has many ethno-medical uses for treating various ailments such as asthma, gastro intestinal, toning up body muscle, toothache, muscle pain, tender leave paste for easy removal of pus from boils, etc as reported by Bhagowati and Changkija, (2009). In Northeast India there are two planting time, kharif and rabi. Kharif cultivation is mainly done in the hilly states of the region which starts in February - March and harvesting is done from May-June onwards up to Nov-Dec. As a rabi crop it is grown in the plains of Assam during September-October. Whereas in the state of Nagaland the farmers practice jhum cultivation (shifting cultivation) in paddy fields as sporadic with summer paddy and also in small homestead garden which can be kept for 2-3 years beyond which the fruit size reduces. In homestead traditional gardens, the farmers prefer to grow the crop in the shade rather in sunny places.

In Jhum cultivation direct seeding is practiced in paddy fields and the peak harvest time is between August-September.

Most of the chilli species and varieties/cultivars cultivated in India contain around 1% capsaicin but *Bhut jolokia* has around 2–4% capsaicin as reported by various researchers (Mathur *et al*., 2000 and Sanatombi and Sharma., 2008). Very high capsaicin content/unit weight (3-5%) in *Bhut jolokia* makes this chilli an ideal choice for extraction industry to reduce the cost of production (George, 2016). Ritesh *et al*., 2000 reported that due to extra ordinary pungency level, oleoresin powder extracted from Naga chilli is predicted to dominate the world market in coming years as the mainstay for riot control. *Bhut jolokia* has above 85% moisture level with a soft texture that leads to short shelf life. Therefore value added items like pickle has good prospect according to the Project report on king chilli processing, 2017, NEDFI. Chilli is a highly perishable vegetable with high rates of water loss and decay. The fruit dehydrates, begin to turn colour and deteriorates within a few days after harvest in ambient condition (Wall and Berghage, 2007). Maturity at harvest is an important factor affecting quality perception and the rate of change of quality during postharvest handling (Florkowski *et al*., 2009). Maturity of a crop is an assessment of physiological development. Physiological maturity is described as the stage of development when a plant or plant part will continue ontogeny even if detached, whereas commercial maturity is the stage of development when the plant or plant part possesses the prerequisite for utilization by consumers for a particular purpose (Wadata *et al*., 1984). Maturity of a crop at harvest directly affects the colour and size and thus its grade. Generally, chilli is harvested when ripe, but it can also be harvested at a green, mature or immature stage (Berke *et al*., 2004). Chilli peppers for processing are usually harvested green because of better quality maintenance during shipping. However, some hot pepper cultivars can be marketed with a mixed skin colour. So harvest time depends on product usage and market destination (Ministry of Agriculture of Guyana, 2010).

After harvest, the commodity is still living as it continues to perform metabolic reactions in order to maintain its physiological system and these cause a reduction of its quality and shelf life. In order to extend the shelf life of the commodity, it is necessary to retard certain deteriorative processes. One such method to extend the shelf life of fresh vegetables is the use of modified atmosphere packaging (MAP) systems (Shewfelt, 1986; Mazza and Jayas, 2001). MAP refers to the technique of sealing actively respiring produce in a polymeric film to modify the oxygen (O2) and carbon dioxide (CO2) levels from ambient conditions(78% N2, 21% O2 and 0.03% CO2) with the package atmosphere (Church and Parsons, 1995). Among different techniques, MAP has been reported to be a cost effective and successful technique for extending postharvest longevity of several fresh horticultural produce (Thompson, 1996; Banaras *et al*., 2002; Zagham, 2003). The packaged produce had also better market acceptability (Gibe, 1999). MAP has been used to extend the shelf life of fruits and vegetables, and is considered to be an effective method in preventing microbial and insect contamination (Cliffe-Byrnes and O'Beirne, 2005).

Fresh red chillies are perishable in nature and a considerable amount of the produce is wasted due to lack of postharvest processing facilities. Drying is the most widely used primary method of food preservation. In the traditional paprika dehydration processes, due to a prolonged exposure to heat, light, and oxygen, a 20–53% loss of the initial carotenoids and thereby the color of paprika has been reported (De-Guevara *et al*., 2002). Non-enzymatic browning is another cause of paprika color degradation. It has been found that the water activity and temperature had a significant effect on the non-enzymatic browning rate of dried red peppers during their storage (Lee *et al*., 1991). Hot air drying (HD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature ranges from 45 to 70ºC (approximately 10% of moisture content), and this reduces drying time to less than 20 hrs. This temperature range gives maximum colour values and minimizes the loss of volatile oils and discolouration (Berke and Shieh, 2001).

Blanching is carried out to inactivate natural enzymes in order to improve color and texture of the product. Blanching has been found to enhance the drying rate of chillies due to cell wall destruction (Turhan *et al*., 1997)

However, the fruit of Naga king chilli, despite of its immense uses and potentiality, is actually very sensitive and vulnerable that the postharvest loss is very high. Therefore, keeping in view the above problems, it was felt necessary to carry out the present investigation entitled “Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments ” with the following objectives:

Objectives

i. To evaluate the quality and shelf life of Naga king chilli as influenced by different maturity stages and packaging materials.
ii. To evaluate the quality and shelf life of different processed products prepared from Naga king chilli harvested at different maturity stages.
iii. To evaluate the colour retention of Naga king chilli as influenced by blanching and different drying methods.

CHAPTER-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In the present chapter, an attempt has been made to review the works done on the Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments under the following heads:

2.1. Influence of maturity stages and packaging materials on quality and shelf life of Naga king chilli.

2.1.1. Influence of maturity stages on quality and shelf life of Naga king chilli.

Maturity of a crop is an assessment of physiological development. Physiological maturity is described as the stage of development when a plant or plant part will continue ontogeny even if detached, whereas commercial maturity is the stage of development when the plant or plant part possesses the prerequisite for utilization by consumers for a particular purpose (Wadata *et al*., 1984). Green peppers for fresh market consumption are manually harvested on multiple occasions throughout the growing season when pericarp wall becomes thick and the fruit reaches typical size (Sargent, 2000). However, estimating pepper maturity at green stage can be difficult even for fruit with similar physical attributes; under certain conditions, green peppers can begin to ripen and change colour during shipping (Tadesse *et al*., 2002). Maturity of a crop at harvest directly affects the colour and size and thus its grade. Generally, chilli is harvested when ripe, but it can also be harvested at a green, mature or immature stage (Berke *et al*., 2004).

Maturity at harvest is an important factor affecting quality perception and the rate of change of quality during postharvest handling (Florkowski *et al*., 2009). Once the fruit is harvested the source of organic compounds for its energy comes from its own reserves. These reserves are depleted by the respiration process causing a decrease in the quality of the commodity (Kays, 1991; Maguire *et al*., 2004). Church and Parsons (1995) indicated that the respiration rate depends on product type, variety and stage of maturity. Varieties and stages of maturity also have great influence on chillies quantity (Kanner *et al*., 2006; Sanatombi and Sharma, 2008). Chilli peppers for processing are usually harvested green because of better quality maintenance during shipping. However, some hot pepper cultivars can be marketed with a mixed skin colour. So harvest time depends on product usage and market destination (Ministry of Agriculture of Guyana, 2010). Mini and Wahab (2002) reported that variety, agro climatic conditions, harvesting stages, postharvest-handling etc. determine the quality parameters of chilli fruits like colour value and pungency chilli fruits. Hence, fixing the correct maturity stage would be helpful in increasing the quality of chillies at lower cost.

Moisture content is the main constituent in chilli peppers. The amount of moisture is dependent on the age and type of pods harvested. In general, chilli contains 83-85.7% of moisture on fresh weight basis (Aykroyd, 1941; Purseglove, 1968).The content differs at various stages of fruit development (Howalder *et al*., 1996). Chilli is a highly perishable vegetable with high rates of water loss and decay. The fruit dehydrates, begin to turn colour and deteriorates within a few days after harvest in ambient condition (Wall and Berghage, 2007). Moisture mean values of 92.179/0.65%, 91.749/0.92% and 90.729/0.87% for green, breaker and red peppers, respectively, were found by Martinez *et al*., 2005. Borah (2003) evaluated biochemical composition of different types of *Bij jolokia* and recorded a moisture content of 88.20% in *Borbih* green and 78.12% in *Borbih* red, while *Lotabih* recorded 88.53% in green and 86.62% in red stage. Bhagawati, (2009) studied on quality assessment of some important chillies and reported a moisture content of 88.71% (green stage) and 83.45% (ripe stage) for *Bhut* Red and 86.76% (green stage) and 82.49% (ripe stage) for *Bhut* Chocolate.

Goojing *et al*., (1999) reported that after 3 weeks of storage at 15-20°C the red ripen stage tomato fruit were found 78.2% rotting but only 47.5% fruit rotting was found in fruits harvested at the mature stage. Moneruzzaman *et al*., 2008 studied on the effect of different stages of maturity and ripening conditions on the physical characteristics of tomato fruit during the process of ripening. They reported that rotting in ripe tomatoes was found always higher during the entire period of storage. At the 3rd day of storage total rotting % was 8.19% that rose to 74.68% on 15th day of storage. On the other hand rotting% in mature green tomatoes being (0%) at 3rd day and 27.31% at 15th day of storage. The decay or rotting (%) is higher in ripe tomato because of higher rate of respiration, more skin permeability for water loss and high susceptibility to decay organism of this type of fruit. Moniruzzamani *et al*., 2015 studied on the quality of winter tomato fruit harvested at different maturity stages and reported that at 11th day of storage, the highest rotting % was at half ripen stage (50.83%) followed by breaker stage (35.83%) and lowest at mature green stage (8.33%).

Shelf life refers to the end of consumer acceptability, and is the time at which majority of consumers are displeased with the product (Labuza and Schmidl, 1985). Ceponis *et al*., (1987) reported that the storage life of pepper fruit was limited by pathological deterioration. Factors like high temperature and humidity favour the development of postharvest decay (Wills *et al*., 1989). Peppers are classified by fruit characteristics, i.e. pungency, colour, shape, flavor, size, and their use (Smith *et al*. 1987; Bosland 1992). Fresh green chilies losses water very quickly after harvest and begin to wrinkle and change colour within a few days without refrigerated storage. Darkening, shriveling or rotting of stem indicates that green chilies were not harvested recently (Bosland and Votava, 2000). Diaz-Perez *et al*., (2007) also in their shelf life studies concluded that rapid water loss was a major determinant of fruit shelf life. Consumer acceptance of vegetables is highly dependent on appearance and flavour (Rocha *et al*., 2013). Samira *et al*, (2013) reported that the marketability of hot pepper fruits on day 8 under the cooler was greater than 96.0% whereas under ambient condition it dropped below 61.0% in *Melka Eshet* and 70.0% in *Mareko Fana*. They also reported that after 16 days of storage all pepper fruits stored at ambient condition were unmarketable and the quality characters were maintained better when harvested at mature green stage and stored under evaporative cooled storage. Moneruzzaman *et al*., 2008 studied on the effect of different stages of maturity and ripening conditions on the physical characteristics of tomato fruit during the process of ripening and recorded that mature green tomato had the maximum shelf life (13 days), followed by half ripe tomato (12 days) and minimum was (10.33 days) for full ripen tomatoes. Similar result was also reported by Hossain *et al*., 1996. Moniruzzamani *et al*., 2015 also recorded the maximum shelf life of 11.3 days in mature green tomatoes followed by breaker stage (8.6 days) and minimum was 7.6 days for half ripen tomatoes.

Sucrose, Glucose and Fructose are the major components of the soluble natural sugars found in pepper fruit (*Capsicum annuum* L.), Nielsen *et al*., 1991. Sweetness in bell pepper appeared to be typical for ripe stages and closely related to glucose, fructose, total sugar, and dry matter content (Luning *et al*., 1994). It is well known that sugars and simple acids are respiration substrates, and the longer the time of fruit respiration, the higher will be the rates of consumption of sugars and acids (Atta-Aly and Brecht, 1995). Sugar content of chilli differs at various stages of fruit development and it generally increases with advancing maturity (Howalder *et al*.,1996). Gorny and Kader, 1998 mentioned an increase in the amount of soluble solids as fruits ripen and decreased once senescence was reached. The sugar content in the fruit tissue depends strongly on the harvest time. In red peppers, total sugar content was reported to be 4.20 percent compared to 2.27 percent in green peppers as reported by Lee *et al*. (1999). Borah (2003) evaluated biochemical composition of different types of *Bij jolokia* and recorded a TSS content (ºBrix) of 4.06 in *Borbih* green and 5.40 in *Borbih* red, while *Lotabih* recorded 2.66 in green and 1.65 in red. Tamilmani (2005) studied on the postharvest shelf life improvement in chilli and found that the TSS increased during ripening. The polysaccharides of the cell wall are broken up with a consequent increase in sugar levels during ripening (Antoniali *et al*., 2007). Jarret *et al*. (2007) found a total sugar content ranged from 0.73 percent to 2.60 percent. TSS reflects the sugar concentration of a fruit (Latifah *et al*. 2008). TSS contents of five pepper varieties harvested at mature-green stage and subjected to two storage conditions showed a significant ($P \leq 0.05$) difference in the TSS contents of the stored fruits except on day 8 and 16 of the storage period which ranged from 3.5°Brix in Mareko Fana stored in the evaporative cooler to 6.43°Brix in the same variety stored at ambient condition on day 8 (Samira *et al*, 2013). Antoniali *et al*. 2007 recorded TSS values of 5.8 to 7.9°Brix in yellow bell pepper assessed at different maturity stage.

Climatic conditions including light and average temperature have a strong influence on the chemical composition of horticultural crops (Klein and Perry, 1982). Although light is not essential for the synthesis of AA in plants, the amount and intensity of light during the growing season have a definite influence on the amount of AA formed. AA is synthesized from sugars supplied through photosynthesis in plants. Outside fruit exposed to maximum sunlight contain higher amount of vitamin C than inside and shaded fruit on the same plant. In general, the lower the light intensity during growth, the lower the AA content of plant tissues (Harris, 1975). Tomato fruit harvested green and ripened at 20°C to table-ripeness contained less AA than those harvested at the table ripe stage (Kader *et al*., 1977). Maturity at harvest, harvesting method, and postharvest handling conditions also affect the vitamin C content of fruits and vegetable (Kader, 1988). The ripening stage as well as environmental factors, affect the vitamin C content in chili peppers (Bayer and Schmidt, 1991; Poiroux-Gonord, 2010; Wahyuni, 2013). Howard *et al*. (1994) also reported differences in ascorbic acid contents between cultivars and that the contents increased with maturity in all cultivars. Total vitamin C of red pepper was about 30% higher than that of green pepper. Bosland and Votava (2000) reported the concentration of ascorbic acid in pepper reaching up to 340 g100 g−1, while others reported ascorbic acid concentrations in green pepper in the ranges of 46.6–243.0 mg 100 g−1 of dry weight (Nisperos-Carriedos *et al*. 1992; Howard *et al*. 1994; Gibbis and O'Garro 2004). Borah (2003) evaluated biochemical composition of different types of Bij Jolokia and recorded an ascorbic acid content of 132.14mg100g-^{1} in borbih green and 2.22 mg100g-^{1} in borbih red, while Lotabih recorded 122.32 mg100g-^{1} in green and 5.84 mg100g-^{1} in red stage. Robi and Sreelathakumary, 2004 estimated the ascorbic acid content in hot chilli (*Capsicum chinense* Jacq) at three maturity stages (colour change, red ripe and withering stage) and in general, recorded the highest ascorbic acid content at red ripe stage. For green mature, breaker and red peppers values of 107.39/1.84, 129.69/3.11 and 154.39/7.56 mg/100 g edible portion were found. The vitamin C content for green mature and breaker peppers stored at room temperature increased up to 10 days of storage, reaching similar values as those obtained for red peppers direct from the plant while, the stored red ripe peppers showed a significant loss in vitamin C content, around 25% (Martinez *et al*. 2005).

The level of ascorbic acid in peppers can vary according to cultivar, stage of maturity, growing conditions (Perez-Lopez *et al*., 2007; Serrano *et al*., 2010). The ascorbic acid content was highest at ripening stage of chilli (Hawaldar and Hossain, 1997). Kumar and Tata, 2009 investigated the ascorbic acid contents in chili peppers fruits at five ripening stages *viz*., Green (M1), Breaker (M2), Red (M3), Red partially dried (M4) and Red fully dried (M5) from seventeen cultivars of *Capsicum annuum* L and one cultivar of *Capsicum frutescens* L. Among eighteen genotypes the *C. annuum* var. IC: 119262(CA2) showed higher ascorbic acid content (mg/100g) FW i.e., 208.0±0.68 (M1), 231.0±0.66 (M2), 280.0±0.31 (M3), 253.0±0.34 (M4) and 173.7±0.27 (M5). The study revealed that the ascorbic acid content gradually increased from green to red ripening while, decreased in the lateral stages (i.e., red partially dried and red fully dried). These results were agreed according to the data reported by Osuna- Garcia *et al*. (1998) and Martinez *et al*. (2005). Reduction in ascorbic acid content is always associated with the increase of surface browning (Wong *et al*. 1994) and degradation of fruit quality. The ascorbic acid content of all hot pepper cultivars harvested at mature-green stage and stored both in the evaporative cooler and ambient condition showed increment until day 12 and then steadily declined afterwards (Samira *et al*,. 2013). Campos *et al*. (2013) reported ascorbic acid content in the seven studied Habanero genotypes which ranged from 187.24 to 281.73 mg/100 g in fruit sample. Shaha *et al*, 2013 studied the total bioactive compound and the antioxidant activities of three varieties chillies Pepper (viz. *Capsicum annum* L. var. *frutescens*; *Capsicum annum* var. *Glabriusculum*; and *Capsicum annum* var. Bell pepper) at three ripening stages green, intermediate (yellow) and red colour and found that vitamin C contents at different ripening stages in all varieties of chillies was found between 80-149.9mg /100g of fresh weight chilli by dye titrametric method with maximum being in bell pepper (149.9mg/100g FW) at the intermediate stage yellow colour followed by red stage while green stage recorded the lowest. Teodoro *et al*. (2013) also reported the vitamin C contents in the range of 54.1 to 129.8 mg/100 g in Habanero pepper accessions (*Capsicum chinense*). Tilahun *et al*., 2013 studied the variability of ascorbic acid contents of seven Indian peppers varieties/accessions from *Capsicum annuum* (CA 97, CCH, K1, KTPL19, Arka Abhir and Bayadagi Kaddi) and *Capsicum frutescens* (CF1) species using High Performance Liquid Chromatography (HPLC) and reported that Bayadagi kaddi variety showed the highest ascorbic acid content (189 mg/100 FW) and the accession CA 97 showed the lowest ascorbic acid contents (55.3 mg/100 FW). Orobiyi *et al*. (2015) reported 84.64 - 192.64 mg/100g ascorbic acid content in the fresh fruits of chilli pepper. Kantar *et al*. (2016) found 146 mg/100g ascorbic acid in *Bhut jholokia*. Mena *et al*. (2018) evaluated ascorbic acid content in *Bhut jolokia* (*Capsicum chinense* Jacq.) genotypes from North East India and recorded an ascorbic acid content of 92.07-301.11 mg/100g.

Capsaicin is chemically known as 8-Methyl-N-Vanillyl-6-Nonenamide. It is sparingly soluble in water, but highly soluble in fats, oils and alcohol. Five naturally occurring capsaicinoids were reported (Crombie *et al*., 1955; Bennett and Kirby, 1968), *viz.*, capsaicin, dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin and homodihydrocapsaicin. Among them capsaicin and dihydrocapsaicin are the major components in most capsicum species (Iwai *et* *al*.,1979) and their pungencies are about two fold higher than the others (Todd *et al*.,1977). Capsaicin is not a single compound but a mixture of various amides. They are denoted by the common name ‘capsaicinoids’ with capsaicin as the dominant species. It is a digestive stimulant and a cure for many rheumatic troubles (Anon, 1964), it can significantly inhibit cycophosphamide induced chromosomal aberration, lipid peroxidation and DNA-strand breakage in bone marrow cells (De, 1997). It has inhibitory effect on the growth of gastric pathogens (Jones *et al*.,1997), chemo-protective properties (Surh *et al*.,1998) and protects against gastric mucosal injury induced by various necrotizing agent (Teng *et al*.,1998). A wide variation in the capsaicin content in chilli fruits has been reported (Tirumalachar, 1967). Capsaicin content in different parts of the fruit (i.e., pericarp, dissepiment and seed) are different. According to Bajaj *et al*. (1978) and Iwai *et al*. (1978), the activity of capsaicinoids synthesizing enzyme is located more in the pericarp than in the dissepiments of capsicum fruits while Purseglove *et al*. (1981) reported that the dissepiments contained the higher amount of capsaicin than in pericarp. The fruits of *Capsicum frutescens* are highly pungent and suitable for extraction of capsaicin (Murthy and Bavajee,1982).

Bajaj *et al*. (1980) found that the capsaicin content of various genotypes of *Capsicum annum* varied from 0.15-0.925 percent of dry weight basis. Ahmed *et al*. (1996) and Sheela (l998) reported that the capsaicinoids content increased with fruit maturation in relation to increased dry matter content. The capsaicin content increases in the order of green fruit<ripe fruit<sundried fruit. Mathur *et al*. (2000) found that the Tezpur variety (*Capsicum frutescense* var. Nagahari) of Indian chilli contained maximum capsaicin (4.28% w/w) and dihydrocapsaicin (1.42%w/w) contributing to a pungency of 855,000 SHU which seemed to be the hottest chilli known so far. Mini and Wahab, 2002 reported that in general, chilli fruits were least pungent when harvested at turning stage (14.7 mg/g) and the pungency showed an increasing trend as the harvesting was progressed from turning to full ripe and withering stage whose finding is in agreement with Ahmed *et al*. (1996) and Sheela (l998). Robi and

Sreelathakumary, 2004 estimated the capsaicin content in hot chilli (*Capsicum chinense* Jacq) at three maturity stages (colour change, red ripe and withering stage) and in general, recorded the highest capsaicin content at withering stage. Sanatombi and Sharma, 2007 evaluated six chilli cultivars belonging to three species of *Capsicum*: *Capsicum annuum* L. (cvs '*Meiteimorok*' and '*Haomorok*'), *Capsicum frutescens* L. (cvs '*Uchithi*' and '*Mashingkha*') and *Capsicum chinense* Jacq. (cvs '*Umorok*' and '*Chiengpi*') and found that the cultivar '*Umorok*' had the highest capsaicin content (2.06%), and was also the most pungent of with 329100 SHU while the cultivar '*Haomorok*' had the least capsaicin content (0.17%) with a corresponding pungency of 26000 SHU. Most of the chilli species and varieties cultivated in India contain around 1% capsaicin but Naga chilli has around 2–4% capsaicin as reported by various researchers (Mathur *et al*., 2000; Sanatombi and Sharma, 2008). George *et al.*, 2009 evaluated the variation of pungency in *Capsicum chinense* among countries of origin and reported that the fruits of *C. chinense* accession PI640900 (USA) contained the greatest concentration of capsaicin (1.52 mg g− 1 fruit) and dihydrocapsaicin (1.16 mg g− 1 fruit). Pandey *et al*. (2010) reported that to achieve maximum pungency (total capsaicinoids) chilli cultivars should be harvested at the stage of full maturity. Buczkowska *et al*. (2013) reported that the highest amount of capsaicinoids (capsaicin and dihydrocapsaicin) was determined in fruits that were harvested at the initial stage of maturity, green fruits (on average 309 mg/kg) compared to fruits turning colour (258 mg/kg) and red fruits (250 mg/kg). Samira *et al.*, 2013 found that capsaicin content at matured green stage varied from 1.6% to 2.5% which appeared to be lower than results of Gibbis and O'Garro (2004), who reported capsaicin content range of 0.3% to 4.1% in green fruits of 28 hot pepper accessions. They also reported that capsaicin % was more at 12th day as compared to at harvest. Mena *et al*. (2018) evaluated capsaicin content in *Bhut jolokia* (*Capsicum chinense* Jacq.) genotypes from North East India and recorded a capsaicin content of 0.75-4.65 %.

2.1.2. Influence of packaging materials on quality and shelf life of Naga king chilli.

After harvest, the commodity is still living as it continues to perform metabolic reactions in order to maintain its physiological system and these cause a reduction of its quality and shelf life. In order to extend the shelf life of the commodity, it is necessary to retard certain deteriorative processes. One such method to extend the shelf life of fresh vegetables is the use of modified atmosphere packaging (MAP) systems (Shewfelt, 1986; Mazza and Jayas, 2001). The modified atmosphere packaging (MAP) technique consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration, reduce moisture loss and decay and extend the shelf life of the products. MAP techniques provide low O2 and high CO2 regimes similar to those achieved by using controlled-atmospheric storage and are theoretically able to maintain desired atmospheres throughout the marketing chain (Beaudry *et al.*, 1992). MAP refers to the technique of sealing actively respiring produce in a polymeric film to modify the oxygen (O2) and carbon dioxide (CO2) levels from ambient conditions (78% N2, 21% O2 and 0.03% CO2) with the package atmosphere (Church and Parsons, 1995). The packaged produce had also better market acceptability (Gibe, 1999). Sealed packaging such as MAP is intended to suppress microbial growth, retard respiration, ripening, and senescence and inhibit oxidative reactions which require free oxygen (Leistner and Gould, 2002). Among different techniques, MAP has been reported to be a cost effective and successful technique for extending postharvest longevity of several fresh horticultural produce (Thompson, 1996; Banaras *et al.*, 2002; Zagham, 2003). MAP has been used to prevent or retard postharvest fruit ripening and associated to biochemical and physiological changes by favourably altering the O2 and CO2 levels around the products (Gonzalez *et al.*, 2004). MAP has been used to extend the shelf life of fruits and vegetables, and is considered to be an effective method in preventing microbial and insect contamination (Cliffe-Byrnes and O’Beirne, 2005). The bijao leaf (*Heliconia* *bihai*) packaging was used to commercialize guava paste and this package provides a pleasant flavor and odour characteristic (Prada *et al*., 2006). In Colombia, the use of different plant leaves as packaging is frequent due to its degradability and its ability to protect fresh or processed products (Diaz, 2012). The use of banana leaf as primary fruit packaging was explored (Forero *et al*., 2014) due to its degradability, easy access, and its potential to preserve the fruit harvested quality. Forero *et al*, 2017 used banana (*Musa paradisiaca*) leaf as primary packaging for lulos (*Solanum quitoense*) in their proposed packaging configuration (lulos packed with banana leaf in plastic crates of 80×60×20 cm) and stored at different storage temperatures to study the effects on postharvest characteristics. They reported that weight losses and the colour changes result of the ripening process were decreased and this packaging configuration is an easy alternative to get and preserve the quality of lulo fruits for a longer storage time.

High temperature increases the vapour pressure difference between the fruit and the surrounding, which is the driving potential for faster moisture transfer from the fruit to the surrounding air (Ryall and Pentzer 1982; Hardenburg *et al*., 1986; Salunkhe *et al*., 1991). Hardenburg *et al*. (1986) also reported that the effective method of maintaining quality and controlling decay of peppers is by a rapid cooling after harvest followed by storage at low temperature with a high RH. Storage temperatures have strong positive correlation with the rate at which physiological, biochemical and microbiological changes occur during storage (Ryall and Lipton 1979; Ryall and Pentzer 1982; Hardenburg *et al*., 1986). Meir *et al*., 1995 reported that using plastic materials such as polyethylene bag packaging was a useful in maintaining the postharvest quality of the pepper fruits as it prevents water loss and fruit softening. The higher physiological weight loss shown at ambient condition can be associated with increased cell wall degradation leading to exposure of cell water for easy evaporation combined with higher membrane permeability due to faster metabolism and ripening rate at high temperature storage (Dumville and Fry, 2000). The unpackaged fruits, jute sack and wooden box offered low protection to the fruits and therefore allowed rapid water loss from the fruits to the surrounding air as was reported by Jobling (2001) that the air movement over the produce was a highly significant factor in determining the rate of moisture loss. For postharvest handling of chilies and peppers, higher temperature is recommended while on the other hand, as temperature is increased, the rate of water loss is also increased (Ozden and Bayindirli, 2002). Quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and RH of the storage conditions (Perez *et al*., 2003). Samira *et al*., 2013 recorded a general decreasing trend in the moisture content of the varieties with storage time under both ambient and evaporative storage conditions. However, the percent decrease in moisture content was pronounced in fruits stored at ambient condition. The difference in moisture contents of fruits under the two storage conditions could be attributed to the lower temperature and higher relative humidity in the evaporative cooler than in ambient conditions which could have reduced the amount and rate of moisture loss. This may be due to the ripening process that undergo throughout the storage period as ripening of pepper fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Goodwin and Mercer 1972; Suslow 2000; Antoniali *et al*., 2007). Moreover, the lower temperature in the evaporative cooler could have reduced respiration rate and thus delayed fruit ripening and subsequently lowered permeability to moisture loss (Atta-Aly and Brecht 1995). Low storage temperature reduces the rate of respiration and physiological activity leading to retarded senescence of fruit in storage (Pinto *et al*., 2004).

Samira *et al*., 2013 subjectively assessed the marketable quality of the five hot pepper varieties fruits. On each sampling time, marketability of the fruits was judged by 22 trained panellists using a 1–9 rating with 1 = unusable, 3 = unsalable (poor), 5 = fair, 7 = good, 9 = excellent to evaluate the fruit quality. The size, colour, firmness surface defects, sign of mould growth and shrinkage were used, as visual parameters for the rating. Fruits that received a rating of five and above were considered marketable while those rated less than five were considered unmarketable.

Gonzalez *et al*., (1999) reported that the storage quality of bell peppers pre-treated with hot water and polyethylene packaging were improved. Gonzalez *et al*., 2004 evaluated the effect of vacuum packaging (VP) and modified atmosphere packaging without vacuum (MAP) on shelf life of fresh cut green pepper stored at 10ºC and 5ºC. They found that microbiological and quality analysis revealed a limit of shelf life of 14 and 21 days, stored at a10ºC and 5ºC respectively. Banaras *et al*., 2005 studied the effect of MAP on the postharvest longevity of mid-season, late-season and green house grown pepper fruits of three cultivars stored at 8ºC and 20ºC. They found that the late season field harvested peppers placed in ambient atmosphere was 10 to 14 days at 8ºC, whereas it was less than 7 days at 20ºC. MAP extended postharvest life for another 7 days at 8ºC and 10 days at 20ºC compared with non-packed fruits held at these temperatures. Muhammad *et al*., (2005) evaluated the effect of modified atmosphere packaging (MAP) on the post-harvest longevity of pepper fruits and found that the MAP extended post-harvest life for another 7 days at 8ºC and 10 days at 20ºC compared with non-packed fruits held at these temperatures. Good quality chilli fruits should be of uniform size, shape, colour, flavour and pungency typical of the variety. It should be firm and have a bright, glossy surface appearance free from bruises, blemishes and insect damage (Acedo, 2006). Kosson and Stepowska, 2006 evaluated the storage quality of green pepper (*Capsicum annunm* cv. Roxy F1) by packing the fruits in PE with different level of perforation (0.0001, 0,001 or 0.1% of total film area) and found that the mean marketable value of peppers stored for 49 days was greatest for fruits packed in non-perforated, followed by PE bags with 0.1% perforation. Chilli pepper packages using LDPE and polypropylene could maintain better quality retention compared with unpackaged controls (Lee *et al*., 2006). Most chilli peppers retain best quality for 2 to 3 days if stored at room temperature (Wall and Berghage, 2007). Sakaldas and Kaynas, 2010 studied the effects of postharvest treatments on quality and biochemical properties of “Maxibell F1” California wonder type peppers at green maturity stage and reported that the quality and biochemical properties reduced with prolonged storage period. Furthermore LDPE based MAP, PVC based MAP and HWD at 40°C were found successful in terms of keeping the parameters as mentioned. Edusei *et al*., 2012 investigated the effect of modified atmosphere packaging (MAP) on the postharvest quality characteristics and biochemical properties of green chilli peppers (*Capsicum annuum* L. cv Legon 18) with Low Density Polyethylene (LDPE) 35 µm Polypropylene (PP) 80 µm and LDPE microperforated 31.75 µm to store fruits at 10°C for four weeks and at 26-34°C (ambient) for nine days. They found that storage of green chilli peppers using MAP at 10°C and also at 26-34°C (ambient) temperature is beneficial in maintaining the quality and extending the marketable/shelf-life of fresh green chilli pepper fruits. Incidence of fruit decay was recorded in the film-packed fruits, but not in the control (Edusei, 2011). The high disease incidence observed with film packaging may be due to high relative humidity and water condensation around the produce, which promote the development of postharvest decay (Coates *et. al*., 1995). Samira *et* al., 2013, reported that marketability of hot pepper fruits under the cooler was greater than 96.0% whereas under ambient condition it dropped below 61.0% in *Melka Eshet* and 70.0% in *Mareko Fana* on day 8. After 16 days of storage, all pepper fruits stored at ambient condition were unmarketable. The extended storage life of pepper fruits stored in the evaporative cooler could be attributed from the increased RH and reduced temperature. Maintaining lower temperature and higher RH in the storage combined with selecting cultivars having long shelf life could improve marketability of pepper for a relatively longer period. The increased RH in the cooler reduces shrinkage of fruits through moisture loss. Shrivelling and discoloration at ambient temperature and rotting in pepper fruits stored in the evaporative cooler storage were major causes for a decline in percent marketability, with time. Singh *et al*., (2014) examined shelf-life enhancement of green bell pepper (*Capsicum annuum* L.) under active modified atmosphere storage. They reported that the shelf life of bell pepper was extended to 49 days in active packages and 42 days with MA packages, as compared to 7 days with non-packed controlled samples at ambient conditions. A shelf-life of 16, 18, 22 and 28 days was observed in chillies packed in microporous, PE-LD, polyolefin and anti-fog films, respectively, as compared to 15 days in the case of control samples, Chitravathi *et al*. ,(2015).

In peppers, MAP slowed down the changes in TSS values, indicating the retardation of ripening due to the treatments. Moreover, the minimum increases in this parameter were recorded from polypropylene and polyvinyl chloride plastic films packaging treatments with 3.93% and 4.13%, respectively (Akbudak, 2007). There was an increase in the TSS contents of all varieties stored both at ambient and in the evaporative cooled chamber until day 8 after which there was a decline in the TSS levels. Initial increase in TSS content could potentially be attributed to moisture loss by the fruits and conversion of organic acids to sugars (Samira *et al*., 2013). The higher TSS contents of pepper stored at ambient condition could be related to the higher temperature that resulted in faster conversion of starch into water-soluble sugars (Getenit *et al*., 2008). This condition could also increase moisture loss from the fruits thereby increasing the concentration of TSS content compared to the evaporative cooler that had higher RH. Ediriweera *et al*., 2014 evaluated the variation in color, in package gases, firmness, physicochemical sensory and microbiological quality on minimally processed bell pepper strips stored at 8-10ºC for seven days. They reported that a gradual variation in TSS in all treatments and control and notably, TSS from day 4 to 7 decreased for all treatments and control. The decreasing trend is often related to the components used as energy partly to carry on respiration and other metabolic functions (Latifah *et al*., 2008). The reduction in the TSS content is probably due to it being used as a respiratory substrate during the metabolic process (Kays, 1991). Nunez *et al*., 2011 recorded a TSS values of 8.73 to 10.16 ºBrix in Habanero chili pepper (*Capsicum chinense* Jacq.).

High temperature which is known to increase enzymatic catalysis that leads to biochemical breakdown of compounds in fruit and vegetables (Yeshida *et al*., 1984) and could be responsible for the reduced ascorbic acid content of pepper stored at ambient conditions (Samira *et al*., 2013). In a study on 11 pepper varieties Khadi *et al*., (1987) found that ascorbic acid ranged from 18.88 to 299.89 mg/100 g fresh weight, and Osuna-Garcia *et al*., (1998) also reported values between 14.8 and 276.6 mg/100 g fresh weight in four different pepper cultivars of New Mexican-type chili. However, values between 100 and 200 mg vitamin C/100 g fresh weight are the most frequently described (Khadi *et al*., 1987; Howard *et al*., 1994; Durust *et al*., 1997; Simonne *et al*., 1997). MAP retarded the conversion of AA to DHA that occurred in air-stored peppers. Other quality attributes of peppers were maintained better in MAP than in air (Howard *et al*., 1994; Howard and Hernandez-Brenes, 1998). Ascorbic acid is most sensitive to destruction when the commodity is subjected to adverse handling and storage conditions; losses are enhanced by higher temperatures, low relative humidity and physical damage (Nunes and Emond, 1999). Lee and Kader, 2000 reported that the content of vitamin C in fruits and vegetables can be influenced by various factors such as genotypic differences, preharvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures. They also reported that higher the intensity of light during the growing season, the greater is vitamin C content in plant tissues. They also suggested that temperature management after harvest is an important factor to retain the vitamin C (ascorbic acid) content of fruits and vegetables and the losses increase at high temperatures and with long storage periods. There were statistically significant decreases in ascorbic acid over a 10 day storage period of unpacked and packaged peppers (Martinez *et al*., 2003, Gonzalez *et al*., 2004). The highest results with respect to ascorbic acid content in our study were obtained from polypropylene treatment (Akbudak, 2007). Campos *et al*., 2013 analysed the fruit of seven *Capsicum chinense* Jacq. var. habanero genotypes and found an ascorbic acid contents (187.24 to 281.73 mg/100 g sample) varied between genotypes. Ascorbic acid in the fruits significantly ($p<0.05$) decreased at both low (4.3°C and 10°C) and ambient (26-32°C) storage temperatures (Edusei and Ofosu, 2013).

During ripening, capsaicin concentration reaches a maximum then it turns over and degrades to secondary products. It is assumed that peroxidases catalyze capsaicinoid oxidation and plays a central role in its metabolism in pepper (Yu *et al*., 2005). Peroxidase activity is lower in fruits which have low moisture content (Bernal and Barcelo, 1996). Lower peroxidase and capsaicin oxidase activity means that the oxidation, or breakdown, of capsaicin will be slower when fruits have low moisture. Thus, both higher rates of synthesis and lower rates of degradation could also contribute to the greater concentration of capsaicin in fruits with low moisture content (Gibbis and O'Garro, 2004; Yu *et al*., 2005). Naik *et al*., 2001, investigated on packaging and storage on commercial varieties of Indian chillies (Guntur and Byadigi) and concluded that capsaicin content showed a decreasing trend irrespective of storage conditions, varieties and packagings *viz*., High Density Polyethylene (HDPE) and Metallised Polyster Polyethylene (MPP). The increasing concentration of capsaicinoids under warmer temperature than at lower temperature might be due to faster ripening as well as loss in moisture content of the fruits (Sathiyamurthy *et al*., 2002). High capsaicin content (2.3%) was also observed in peppers subjected to ambient storage conditions than in those stored in the evaporative cooler (Samira *et al*., 2013).

2.2. Influence of different maturity stages on quality and shelf life of different processed products of Naga king chilli.

Value addition is a term frequently mentioned when discussing the future probability of agriculture. It necessarily involves processing and preservation of the commodities which otherwise get disposed at cheaper price or lost without intellectual and technical inputs. It is a process of changing or transforming a product from its original state to a more valuable state. Generally, value is added to increase the shelf life and storage ability. There lies a great scope in value addition (Singh *et al*., 2004) in India; this value addition has vital importance due to diversity in socio-economic condition, industrial growth, urbanization and globalization. Recently, the demand for value added products prepared from chilli like, dried pods, flakes, powder colour oleoresin, pungent oleoresin etc. has been steadily increasing. In food beverage industry chilli has acquired a great importance in the form of oleoresin which permits better distribution of colour and flavour as compared to chilli powder. Studies have shown that adsorption chromatography could be used for fractionization of pungency and colour constituents. The Regional Research Laboratory, Trivandrum developed a process which aimed to separate the chilli oleoresin into two fraction, a highly pungent fraction and a natural chilli clear fraction free from pungency. The pungent one can be used for pharmaceutical purposes and the colour free for colouring products (Pruthi. 1989). The immense horticultural, agricultural and biological diversity has made chilli globally important as a fresh and processed vegetable and a source of ingredient for sauces and powders and as a colorant (Bosland and Votava, 2000). There is a wide range of chilli products based on whole or ground chilli entering the world trade. These are used in whole dried or chopped form or as ground powder. Green chilli powder has many applications for use with man food adjuncts in place of fresh green chillies. The powder can be used for sprinkling on products such as potato wafers, chips finger fries extruded products, sandwiches, pizzas, burgers etc. Green chilli powders are self-stable and can be preserved for over 6 months (Kanwar, 2000). The quality parameters of the stored dehydrated capsicum based products that are important to spice formulators are, in addition to microbiological status and absence of insect infestation, the retention of characteristic color, characteristic aroma, and content of capsaicinoids (Govindarajan *et al*., 1987; Berke and Shieh, 2012). Non-enzymatic browning is another cause of paprika color degradation. It has been found that the water activity and temperature had a significant effect on the non-enzymatic browning rate of dried red peppers during their storage (Lee *et al*., 1991). According to Bosland (1993), the quality of dry fruit products, like red chilli and paprika, is based on their redness of colour and pungency level, which is usually obtained from *C. annuum* peppers. The quality of chilli powder is based on visual and extractable colour, pungency level and to a lesser degree the nutritive value. Dehydrated products derived from pepper, like paprika (powder) and oleoresin, are concentrates of carotenoid pigments and the colour of the material is an important quality parameter (Minguez-Mosquera and Perez-Galvez, 1998). The improvement in food science and technology has contributed to enhance the food drying and their use in both small and large industrial scale. Drying is the oldest method to preserve food for long periods. Furthermore, drying vegetables results in concentration of flavour and nutrients (Nogueira *et al*., 2003). Cheul *et al*., (2010) reported that Capsaicin and tocopherol in red pepper seed oil enhances the thermal oxidative stability during frying indicating the importance of pepper in food industry. However, the thermal processing of pepper affects the physic-chemical qualities of the final product (Kolawole and Olaniyi 2010; Raji *et al*., 2010). The high nutritive and culinary value of pepper gives them a high demand in the market year round. Capsicum spps. are used fresh or dried, whole or ground into powder and alone or in combination with other flavoring agents. Pepper is used as one ingredient in production appetizers (Premavalli and Amrinder, 2010). Dried chilli is a spice product and the one most widely used as condiments for flavouring and colouring in Asian cuisines (Toontom *et al*., 2010). Off shaped but high quality bell pepper are available in the local market, which are non-marketable due to their appearance. This type of commodities could be subjected to minimal processing and be sold at local supermarkets as a value added products (Ediriweera *et al*., 2014).

The quality of dried chilli is assessed by a number of different parameters such as colour, hotness, ascorbic acid content and volatile flavour compounds (Kim *et al*., 2006; Wang *et al*., 2009; Yaldiz *et al*., 2010). For the use of chili peppers as vegetables the quality relies mainly on freshness, pungency and some nutrient factors such as a high vitamin C content. For dried chilli peppers used as spice for home cooking or in the food and cosmetic industry, the quality parameters are versatile and can be categorized to four groups (Buckenhuskes, 2003).

Drying is one of the common preservative methods for bell pepper. Drying lowers water activity which increases shelf-life of the product, reduces the storage volume and decreases transport costs (Ade-Omowaye *et al*., 2003; Vega *et al*., 2007). The dried product has a number of applications. Auto-catalyzed degradation of carotenoids occurs in ground chilli powder due to which its colour is not stable during storage in ground form. Colour retention is influenced by storage temperature and moisture content (Malchey *et al*., 1982). High colour value paprika is prepared by grinding only the fruit pods, whereas low-colour paprika is prepared by grinding the pods containing seeds. The seeds decrease the overall colour value of the spice (Farrell, 1990). The amount of carotenoids is important for the quality of dried chili pepper powders and in addition, some of them show a pro-vitamin A activity (e.g. β-carotene) and are essential phytonutrients (Bosland and Votava, 2012; Gomez-Garcia and Ochoa-Alejo, 2013).

Garruti *et al*., 2013 evaluated the flavour acceptance by hedonic scale to compare the sensory quality and the volatile compound profile of new varieties of *Capsicum chinense* pepper. The samples did not differ in terms of flavour acceptance, but they showed differences in aroma quality confirming the differences found in the volatile profiles. All *Capsicum chinense* peppers showed good acceptability, reaching mean hedonic rates around 7 which corresponds to "like moderately" in the hedonic scale, with no statistical difference between means ($p > 0.05$) indicating that the three varieties were well accepted by the judges, who showed no preference for one over the others. However, the samples showed differences in the frequency distributions of the hedonic values rated by the judges where Biquinho samples received higher frequency of "liked extremely" (9) and in the indifference category (5 = neither like, nor dislike).

Shelf life of agricultural commodity, including spices is significantly influenced by its moisture content and is frequently an index of quality (Bradley, 2010).

Processing methods and cooking procedures can result in significant losses of vitamin C (Fennema, 1977). High concentrations of ascorbic acid in fresh fruits together with a suitable drying and milling technology are important for achieving high quality chilli powders. Vitamin C helps to protect and preserve other valuable compounds. An example is the protection of carotenoids and thereby maintaining colour intensity during the drying process and storage of chilli powder (Biacs *et al*., 1992). Howard *et al*. (1994) reported that 75% of ascorbic acid in red chilli was lost during drying, with the final content of ascorbic acid being in a range from 12.0 to 44.4 mg/100 g. While fresh chilli peppers are a rich source of vitamin C, the content in dried fruits is degraded to residual levels of only 10% or less (Ramesh *et al*., 2001). Dehydration of peppers resulted in an 88% decrease in ascorbic acid content (Martinez *et al*., 2005). Vega-Galvez *et al*., (2008) reported that temperature in the hot air drying (HD) method had a detrimental effect on the retention of ascorbic acid which was because heated air inherently exposes the products to oxidation, thus reducing their ascorbic acid content. The ascorbic acid contents of all of dried chilli was significantly different among the samples ($P \leq 0.05$) and the ascorbic acid contents of all dried chilli varied between 14.21 and 51.55 mg/100g , whereas, the ascorbic acid content of fresh chilli was 53.19 mg/100g (Toontom *et al*. ,2012). Reis *et al*., 2013 evaluated the effect of drying temperature on the nutritional and antioxidant qualities of Cumari peppers from Para (*Capsicum chinense* Jacqui) and found that the content of vitamin C for the dried pepper differed significantly ($P < 0.05$) compared with the fresh pepper as the micronutrients (ash and vitamin C), together with the phenolic compounds, capsaicin and antioxidant activity, were degraded by the use of high temperatures.

Thermally-treating chilli at 210ºC was reported to increase the capsaicin content of chilli. This was caused by the dehydration of the food matrix and improved extractability of capsaicin by cell disruption during the thermal process (Schweiggert *et al*., 2006). Lannes (2007) evaluated the species *C. chinense* and encountered capsaicin concentrations of 4.0 mg. g^{-1} and dihydrocapsaicin concentrations of 2.4 mg. g^{-1} for samples dried at 60 ºC for 72h. Bhagawati (2009) observed a decrease in capsaicinoid content in all the products when compared with that of fresh chillies where *Bhut* Red recorded the highest capsaicin (25906.49µgg-^{l}) content in whole dried pods as compared to paste (16991.22 µgg-^{l}) and powder (25547.45 µgg-^{l}), while *Bhut* Chocolate recorded a capsaicin content of (25676.03 µgg-^{l}) in whole dried pods, (16775.82 µgg-^{l}) in paste and (24115.35 µgg-^{l}) in powder. The decrease might be due to the fact that heating and mincing of chilli pods results in disruption of plant tissue releasing capsaicinoids which then get susceptible to degradation (Suzuki *et al*., 1980). Products made of whole hot pepper fruits contain more capsaicinoids. They are more pungent in taste compared to those made of the pericarp alone (Nowaczyk 2011). Toontom *et al*., 2012 reported that the capsaicin content and hotness of dried chilli from all the drying methods were higher than in the fresh chilli sample ($P \leq 0.05$). The lower capsaicin content in fresh chilli may due to the peroxidase enzyme by catalytic activity. Whereas, dried chilli samples were treated by blanching before drying for inactivating that enzyme. The similar result was reported by Schweiggert *et al*., (2006) and Topuz *et al*., (2011). Giuffrida *et al*., (2014) studied the pungency of red chili pepper powder during one year of storage at room temperature (20-24. °C) and at low temperature (- 18. °C). During storage at room temperature, capsaicinoid amount was found to decrease progressively following a linear kinetics. After 12 months total capsaicinoids decreased to 75% of the initial value. Capsaicinoids may vary with the method of processing (Zewdie and Bosland, 2001). It has been reported by Kirschbaum *et al*., 2002 that capsaicin and dihydrocapsaicin diminishes after cellular disruption of the fruits which is apparently due to temperature dependent oxidation. It may further loss up to 16.1 to 35.7 percent during blanching and drying (Orak and Demirci, 2005).

2.3. Influence of blanching and different drying methods on colour retention of Naga king chilli.

Not only health promoting attributes are important for the usage of chillies. The xanthophylls (capsanthin and capsorubin) are the dominating carotenoids, which allow the production of natural colorants such as oleoresins. These products are used in the food and cosmetic industries (Minguez-Mosquera *et al*, 1992; Minguez-Mosquera, 1998). Forthcoming regulations will tend to restrict the use of foodstuff colorants exclusively to natural compounds, while artificial compounds will disappear progressively from the lists of acceptable colorants (Chambolle, 1992). Moreover, colour is important for pricing of paprika and chilli peppers in international trade. It relies mainly on the content of extractable carotenoids. The amount of carotenoids is measured by the American Spice Trade Association (ASTA) method 20.1 (ASTA, 1997). Therefore, it will be necessary to evaluate the processing steps that affect the nature of these colouring matters so that the industry can develop profitable processes with homogenous stable and safe products (Ibrahim *et al.*, 1997). Carotenoids are sensitive to oxidative conditions such as low water activity. Water contents of approximately 15% can enhance the stability of carotenoids during storage and reduce the degradation of colour (Osuna-Garcia and Wall, 1998). However, these rather high water contents increase the growth of bacteria and mold, so a water content of approximately 11% for dried *Capsicum* powder is recommended (Buckenhuskes, 2003). Beside pungency, the colour of paprika or chilli powder is an essential parameter in quality assessment. The typical red colour, required for industrial purposes, is caused by the content and pattern of more than 30 different carotenoids (Buckenhuskes, 2003). The indiscriminate use of synthetic colours for the food colouring has several harmful effects. This necessitates focus towards natural colours for food colouring (Prasath and Ponnuswami, 2008).

Fresh red chillies are perishable in nature and considerable amount of the produce is wasted due to lack of postharvest facilities. Colour retention is influenced by storage temperature and moisture content (Malchey *et al.*, 1982). High colour value paprika is prepared by grinding only the fruit pods, whereas low-colour paprika is prepared by grinding the pods containing seeds. The seeds decrease the overall colour value of the spice (Farrell, 1990). Drying is the most widely used primary method of food preservation. Sun drying is a slow process that is weather dependent and is thus difficult to control. This exposes the product to environmental hazard and results in products of low quality. Long dehydration times lead to poor quality products due to factors which include caramelisation, Maillard reactions, enzymatic reactions, pigment degradation and L-ascorbic acid oxidation (Horner, 1993). Many factors affect the time needed for drying foods: temperature, air circulation, humidity and the kind of food being dried. Generally, vegetable dehydration process occurs in two main steps: milling and drying. They are responsible for, respectively, 50% and 20% of carotenoid losses. Furthermore, in the drying step, undesirable changes of taste and color due to prolonged heat exposition are frequently observed. The colour preservation is the main limitation of artificial drying. Traditionally, dried chilli is obtained by sun drying (SD), Condori *et al.*, 2001. It takes about 7-20 days (depending on the weather conditions) to reduce the moisture content to 10-15% (Hossain, 2003). In the traditional paprika dehydration processes, due to a prolonged exposure to heat, light, and oxygen, a 20–53% loss of the initial carotenoids and thereby the colour of paprika has been reported (De-Guevara *et al.*, 2002). Non-enzymatic browning is another cause of paprika colour degradation. It has been found that the water activity and temperature had a significant effect on the non-enzymatic browning rate of dried red peppers during their storage (Lee *et al.*, 1991). Many factors such as cultivar, temperature of drying, oxygen/air atmosphere, temperature, and moisture content during storage affect the retention of colour (Walker, 2011).

Giuffrida *et al*., (2014) studied the colour of red chilli pepper powder during one year of storage at room temperature (20-24. °C) and at low temperature (-18°C). During storage at room temperature, carotenoid amounts were found to decrease progressively following a linear kinetics. After 12 months free carotenoids decreased to 20% of the initial value.

2.3.1. Influence of blanching on colour retention of Naga king chilli

Blanching is a pretreatment carried out primarily to inactivate natural enzymes (Cano *et al*., 1990) and loosens tissues which results in a faster drying process. Blanching is carried out to inactivate natural enzymes in order to improve colour and texture of the product and it has been found to enhance the drying rate of chillies due to cell wall destruction (Turhan *et a*l., 1997). Oil water blanching was observed to increase the drying rate and the resultant dried samples had higher colour when compared with untreated samples. Blanching is usually done by water and steam blanching but in some cases oil/water blanching has been carried out (Akanbi *et al*., 2003). Gupta *et al*., 2002 studied on the drying characteristics of red chilli and found that inactivation of peroxidase enzyme was achieved by blanching chillies at 90ºC for 3 min in hot water and the product quality in respect of pigment retention and non-enzymatic browning indicated that the blanched red chillies should be dried at 55ºC. Vega-Galvez *et al*., (2008) reported that the colour of the dried samples reduced with increase in drying temperature in which the highest air-drying temperature (90ºC) presented the lowest value of colour while the maximum was at air-drying temperature of 70ºC. The colour content is mainly attributable to endogenous carotenoids thus the colour content will be directly related to deterioration in these pigments due to high drying temperatures. The colour of the pretreated dried pepper samples was generally higher than that of the dried untreated samples. This may be due to the fact that blanching reduces the enzymatic browning and prevents the loss of colour (Chung *et al*., 1992). Shivhare *et al*., (2000) found that the blanching paprika at 100°C for up to 3 min was recommended on the basis of product quality, however the drying rate decreased while paprika was blanched for 3 minute. Hossain *et al*., (2007) found faster drying and higher colour value for the blanched sample rather than unblanched sample. On the contrary, Anoraga *et al*., (2018) reported that steam blanching pretreatment was the best pre-drying method because it can maintain the vitamin-C content and colour of chilli fruit. Pretreatments methods which include blanching, chemical pretreatment and osmotic dehydration improve nutritional quality of the dried products as well as reduce the dehydration time of the drying process (Akanbi *et al*., 2003; Kingsly *et al*., 2007). Hossain *et al*., 2007 conducted a single-layer drying experiments under controlled conditions of temperature, relative humidity (RH) and air velocity to find out the effects of drying conditions and blanching on the drying rate and colour of Thai red chilli. Drying rate increased with an increase of drying air temperature and a decrease of RH. Faster drying rate and higher colour value was found for the blanched sample rather than the unblanched sample.

2.3.2. Influence different drying methods on colour retention of Naga king chilli

Hot air drying (HD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature ranges from 45 to 70ºC (approximately 10% of moisture content), and this reduces drying time to less than 20 hrs. This temperature range gives maximum colour values and minimizes the loss of volatile oils and discolouration (Berke and Shieh, 2001). As a general rule the temperature should not exceed 50-60°C with less than 50 hrs drying period (Zapata *et al*., 1992). Low drying rate gave superior color quality, (Minguez-Mosquera *et al*., 1994; Ibrahim *et al*, 1997). Freshly harvested red chilli (*Capsicum annum* L) of variety 'CH-3' was subjected to conventional sun-drying (CSD) and drying in the batch-type dryer (BTD) using indirect hot air to evaluate two chilli drying methods with respect to temperature and time combination, quality parameters including the physico-chemical and microbial attributes. It took 25 h to bring down the moisture content of chillies from 361 to 10.1% (db) in the BTD as against 10 days by the CSD technique for bringing down the moisture content to 9.9% (db). The colour retention was significantly better in the chillies dried using BTD as compared to CSD (Oberoi *et al*., 2005). Hot air drying has been identified by a number of authors as a more efficient drying method. This is due to the fact that heat and mass transfer can be controlled during the drying process to achieve desired product quality. Hot air drying however results in depletion of some food nutrients as well as undesirable colour and textural changes (Adedeji *et al*., 2008).

Common paprika ASTA colours preferred in the industry are 85, 100, 120 and 150 (Tainter and Grenis, 1993). Paprika with 200 ASTA colour units would give a brighter red to a finished product than an equivalent amount with 100 ASTA colour units (Wall and Bosland, 1998). After 4 months storage, Pepper from Djala region lost 29.09 % (from 225.95 to 180.53 ASTA), while that from Stara Pazova lost 20.10 % (from 206.73 to 146.59 ASTA) of the initial colour (Tepic and Vujicic, 2004). Generally, in trade the lower limit allowable for chilli powder is 120 ASTA units and for non-pungent paprika, it is 160-180 ASTA units (Hari *et al*., 2005). Lannes *et al*., 2007 found that at least 18% of the fruits of *Capsicum chinense* accessions has ASTA values above 200 units. For chili peppers, values lower than 120 ASTA units are usual (Nieto *et al*., 1999; Zachariah and Gobinath, 2008). Sweet, non-pungent powders have ASTA 20.1 values of 160-180 and for hot chili powders ASTA 20.1 values of 120 are reported (Zachariah and Gobinath, 2008). Shiva *et al*., 2014 assessed the variability in paprika alike chillies (26 indigenous germplasm) and paprika lines (18 exotic collections) for yield and quality attributing parameters and found that ASTA colour units ranging from 124 to 360 (indigenous) and 79 to 356 (exotic). Koncsek *et al*., (2016) evaluated the extractable (ASTA) colour retention of four different milled spice paprikas at 10, 20, 35, 50, and 60 °C storage temperature and found that the ASTA colour stability during long-term storage period strongly depended on the temperature, primary handling and drying of the fresh crop, and the applied production technology.

CHAPTER-3

MATERIALS AND METHODS

MATERIALS AND METHODS

The present experiment entitled **"Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments"** was carried out at the laboratory of Department of Horticulture, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus during the year 2016-17 & 2017-18. Samples were collected directly from the local farmers under Dimapur district, Nagaland. The details of methodology followed in the experiment for recording various observations and analyzing the data are discussed below.

3.1. General information

3.1.1. Location

The fruit samples of different maturity stages *viz*., matured green, turning and red stage were collected from the farmer's field at Tsupama Village, Dimapur district, Nagaland. The analytical works were conducted at the laboratory of Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus.

3.1.2. Climatic condition

The climatic condition of the farmer's field is of sub-tropical type. Details of the meteorological data during the period of investigation is presented in Table 1 and Figure 1.

3.1.3. Soil

The soil of the farmers field, in general, is clayey loam, well drained and acidic in nature.

3.2. Experimental details

3.2.1. Materials

The fruit samples of different maturity stages viz., matured green, turning and red stage for experiment-I & II and the fruits of same maturity stage i.e., red stage for experiment-III were collected from the farmer's field and brought immediately to the laboratory. The samples were then subjected to various treatments.

3.2.2. Technical Programme

3.2.2.1. Experiment-I: Influence of different maturity stages and packaging materials on quality and shelf life of Naga king chilli.

Experimental design: Completely Randomized Design (CRD)

Number of replications: 3(three)

Level of maturity treatments: 3 (three)

Number of packaging treatments: 4(four)

Number of fruits/treatment: 5 fruits

Interval of observation: 2 days

Period of investigation: 2 years (2016-17 & 2017-18)

Treatment Details:

a) **Maturity stages (M):**

M_1-Matured green stage

M_2-Turning stage (green to orange)

M_3-Red stage

b) **Packaging materials (P):**

P_0- No packing

P_1- Newspaper

P_2- Perforated PE

P_3- Banana leaf

Treatment combinations:

M_1P_0: Matured green stage with no packing treatment.

M_1P_1: Matured green stage packed in newspaper and stored at ambient condition.

M_1P_2: Matured green stage packed in perforated polyethylene bags and stored at ambient condition.

M_1P_3: Matured green stage packed in banana leaf and stored at ambient condition.

M_2P_0: Turning stage with no packing treatment.

M_2P_1: Turning stage packed in newspaper and stored at ambient condition.

M_2P_2: Turning stage packed in perforated polyethylene bags and stored at ambient condition.

M_2P_3: Turning stage packed in banana leaf and stored at ambient condition.

M_3P_0: Red stage with no packing treatment.

M_3P_1 : Red stage packed in newspaper and stored at ambient condition.

M_3P_2: Red stage packed in perforated polyethylene bags and stored at ambient condition.

M_3P_3: Red stage packed in banana leaf and stored at ambient condition.

Methodology: The Fruits of different maturity stages *viz*., matured green, turning and ripe stage were collected from farmer's field and brought immediately to the laboratory. The samples were subjected to various treatments of different packaging materials.

3.2.2.2. Experiment-II : Influence of maturity stages on different processed products of Naga king chilli.

Experimental design: Completely Randomized Design (CRD)

Number of replications: 3(three)

Level of maturity: 3(three)

Number of processed products: 3 (three) *viz*., whole dried pod (V_1), paste(V_2) & powder(V_3)

Number of fruits/treatment: 5 (five)

Interval of observation: 30 days

Period of investigation: 2 years (2016-17 & 2017-18)

Treatment Details:

Maturity stages (M):

M_1- Matured green stage

M_2- Turning stage (green to orange)

M_3-Red stage

Treatment combinations:

V_1 M_1: Matured Green Chillies processed into whole dried pod.

V_1 M_2: Turning stage Chillies processed into whole dried pod.

V_1 M_3: Red stage Chillies processed into whole dried pod

V_2 M_1: Matured Green Chillies processed into Paste.

V_2 M_2: Turning stage Chillies processed into Paste.

V_2 M_3: Red stage Chillies processed into Paste.

V_3 M_1: Matured Green Chillies processed into Powder.

V_3 M_2: Turning stage Chillies processed into Powder.

V_3 M_3: Red stage Chillies processed into Powder.

Methodology: The fruits of different maturity stages were collected from farmer's field which was then immediately brought to the laboratory for preparation of various value added products.

3.2.2.3. Experiment-III: Influence of blanching and different drying temperatures on colour retention of Naga king chilli.

Experimental design: Completely Randomized Design (CRD)

No. of replications: 4(four)

No. of blanching treatments: 2 (two)

No. of drying temperature treatments: 4(four)

No. of fruits/treatment: 5(five)

Interval of observation: 45 days

Period of investigation: 2 years (2016-17 & 2017-18)

Treatment Details:

a) **Blanching (B):**

B_0– No blanching

B_1– Blanching

b) **Drying Temperatures (T):**

T_0 - Sundry

T_1 – 50º C

T_2 – 60º C

T_3 – 70º C

Treatment combinations:

B_0T_0: Unblanched red stage fruits and sundried.

B_0T_1: Unblanched red stage fruits dried at 50º C.

B_0T_2: Unblanched red stage fruits dried at 60º C.

B_0T_3: Unblanched red stage fruits dried at 70º C.

B_1T_0: Blanched red stage fruits and sundried.

B_1T : Blanched red stage fruits dried at 50º C.

B_1T_2: Blanched red stage fruits dried at 60º C.

B_1T_3: Blanched red stage fruits dried at 70º C.

Methodology: The fruits of same maturity stage (red stage) were collected from farmer's field in Dimapur district and was given different treatments *viz.*, blanching and different drying temperatures. The samples were dried to the desired moisture level, packed (5fruits each) in LDPE and stored at ambient condition.

3.3. Observations recorded

3.3.1. Physical parameters

3.3.1.1. Moisture (%)

The moisture content was determined by using oven dry method (100ºC) as per the procedure of A.O.A.C. (1984). The samples of each replication from all the treatments were taken for measuring initial weight and then dried in the oven until they attained a constant weight. The moisture % was then calculated with the use of the following formula:

$$\% \, Moisture = [(initial\ wt. - final\ wt.) / initial\ wt.] \times 100$$

3.3.1.2. Rotting (%)

Rotting percentage was calculated based on the number of fruits that was rotten during the observation dates. Ten (10) fruits were used in each replication for all the treatments. It was expressed in percentage following the formula:

$$\% \text{ of rotting} = \frac{No.of\ rotten\ fruits}{Total\ No\ of\ fruits} \times 100$$

3.3.1.3. Sensory evaluation (9 Point Hedonic Scale)

Sensory qualities (appearance, aroma and overall acceptability) of the products were assessed by 9 point hedonic scale as per the procedure developed by Peryam and Giradot (1952). The scale or the rating scored expresses how much the product is liked or accepted by the panellists.

9 Point Hedonic Scale:

DISLIKE EXTREMELY	DISLIKE VERY MUCH	DISLIKE MODERATELY	DISLIKE SLIGHTLY	NEITHER LIKE NOR DISLIKE	LIKE SLIGHT-LY	LIKE MODERATELY	LIKE VERY MUCH	LIKE EXTREMELY
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

3.3.1.4. Shelf life (days)

Shelf life was calculated by counting the days from the date of fruit storage to the date on which the fruit become unmarketable.

3.3.2. Chemical parameters

3.3.2.1. Total Soluble Solids (TSS ^{o}Brix)

Juice was extracted from the fruit in a blender then filtered using funnel with filter paper in a beaker. The filtrate was taken for TSS determination by placing one drop of clear juice on the prism of the hand refractometer with a dropper. Between samples, the prism was cleaned with tissue paper and distilled water and dried before the next use. The refractometer was standardized against distilled water (0^{o} Brix TSS). The results thus obtained were expressed as ^{o}Brix as per A.O.A.C. (1984).

3.3.2.2. Vitamin C (mg/100g)

Ascorbic acid content of fruit was estimated by 2, 6 dichlorophenol indophenol dye titration method as suggested by Sadasivam and Manikam (1992).The data thus obtained were expressed in mg/100 g of pulp. The formula used for calculation was:

$$\text{VitaminC}= \frac{Titre\ value\ x\ dye\ factor x Vol.make\ up\ (25ml)}{Aliquot\ of\ sample\ taken\ for\ determination\ (5ml) x Vol.of\ sample\ for\ estimation\ (2.5ml)} \text{x } 100$$

3.3.2.3. Capsaicin (μg/g)

The capsaicin content was determined with HPLC (High Performance Liquid chromatograph) using the AOAC Official method 995.03 (AOAC, 1995) and was expressed in μg/g.

Extraction procedure:

- 1gm crude sample + 10mL acetonitrile
- Sonicate for 4 hrs at 80ºC
- Cool down at room temperature
- Centrifuged
- Supernatant collected
- 100uL supernatant + 900uL Mobile phase
- Filtered and estimated

3.3.2.4. Extractable colour (ASTA units)

Total extractable colour was determined by the methodology proposed by American Spice Trade Association (ASTA 20.1, 1997) and was expressed in ASTA colour units/g dry matter.

Procedure: The dried fruits were finely ground with the help of mortar and pestle then sieved and 0.7 to 1.0g was weighed and placed in an amber coloured 100 ml volumetric flask and the volume was made up with acetone. The flasks with the samples were capped and left in the dark at room temperature for 16 h for colour extraction. An aliquot of this solution was used for the spectrophotometric measurement at 460 nm wave length using the solvent acetone as blank.

ASTA units were calculated as follows:

$ASTA\ Extractable\ color = Absorbance$ at 460 nm x 16.4/ $Sample\ weight$(g)

3.3.3. Statistical analysis:

The data recorded during the period of investigation were computed, analysed and inferred for significant test in accordance with the procedure outlines by Panse and Sukhatme (1989). The significance of different sources of variations were tested by error mean square using Snedecor "F" Test of probability at 5 percent level of significance.

Table. 3.1: Meteorological data recorded during the period of investigation September-March, 2016-17 and 2017-18

Year	Temperature (^{o}C)				Relative Humidity (%)			
	2016-17		2017-18		2016-17		2017-18	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
September	32.5	23.9	31.6	24.5	94	73	95	74
October	31.6	21.8	30.3	22.0	94	70	95	75
November	27.8	15.8	28.1	16.3	95	64	96	63
December	26.5	11.1	25.5	12.3	94	54	96	66
January	25.0	8.7	23.7	9.6	94	49	97	63
February	28.2	10.4	26.1	10.8	93	42	97	54
March	28.2	14.0	30.2	14.5	93	47	95	49

(Source: ICAR Nagaland Center)

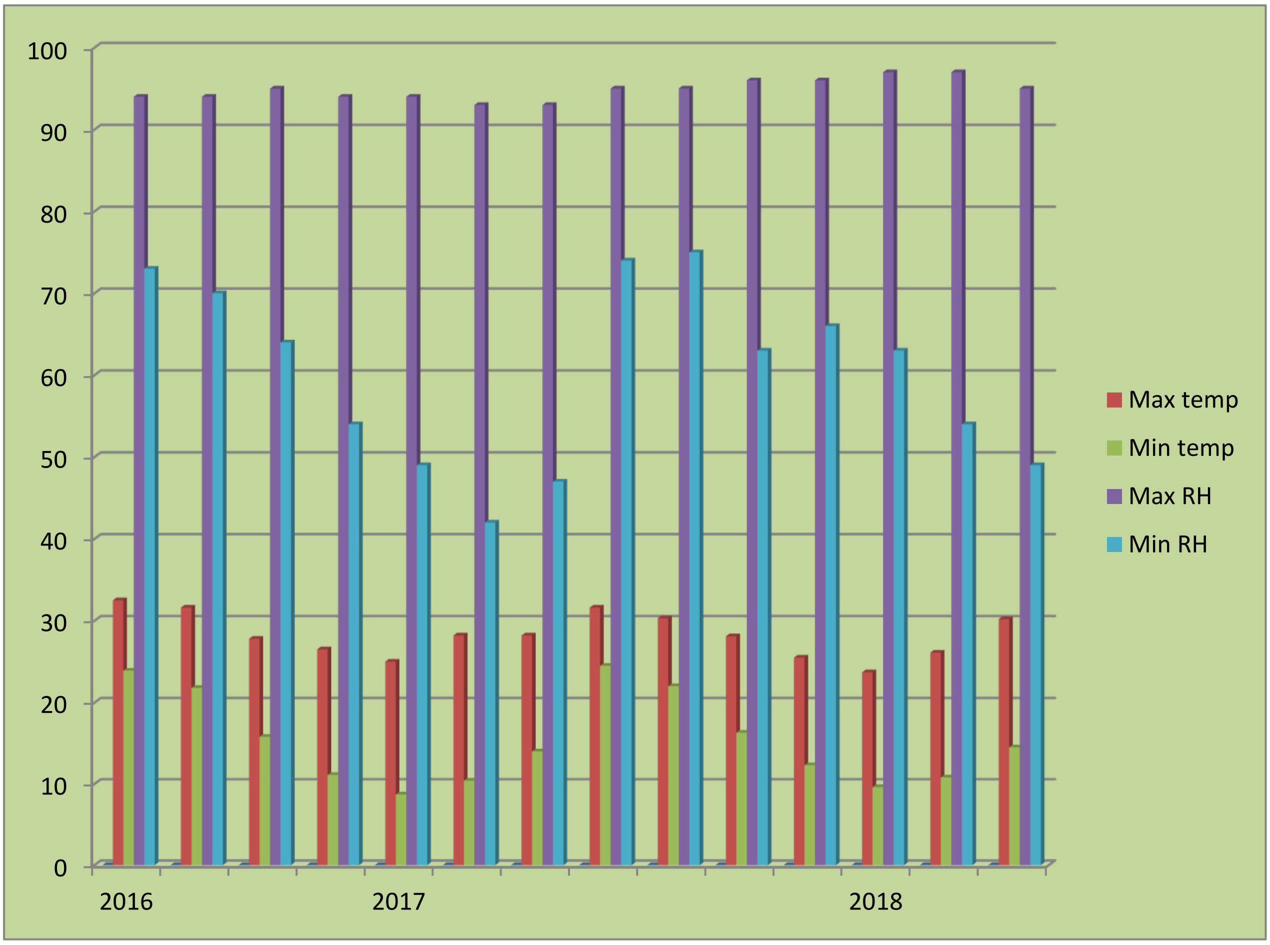


Fig. 3.1 Meteorological data recorded during the period of investigation (September-March, 2016- 17 and 2017-18)

CHAPTER- 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

In this chapter, the results of the present investigation entitled "Quality and shelf life of Naga king chilli (*Capsicum chinense* Jacq.) as influenced by maturity stages and postharvest treatments " are embodied with tables, figures and plates and discussed with available relevant literature.

4.1. Influence of different maturity stages and packaging materials on quality and shelf life of Naga king chilli.

4.1.1. Moisture content (%)

Maturity stages (M)

Table 4.1. presents the effect of different maturity stages on moisture content of Naga king chilli fruits. The maturity stages had significantly influenced the moisture content on all dates of observation during first year, while it failed to reach significance level on the second year. However, in pooled data, it showed significant influence. In general, the moisture content decreased gradually with storage time irrespective of the maturity stages. This may be due to the ripening process that undergo throughout the storage period as ripening of pepper fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Goodwin and Mercer 1972; Suslow 2000; Antoniali *et al*., 2007). In both the years of observation as well as in pooled data, it was observed that matured green (M_1) gave the highest moisture content on the final date of observation (73.22%, 75.02%, 74.12%) while the lowest was recorded in red stage i.e., M_3 (70.74%, 72.33%, 71.53%) respectively. The present finding of a

Table 4.0: Initial values

Moisture (%)

	2016-17	2017-18	Pooled
M1	89.0	87.66	88.33
M2	88.20	86.91	87.55
M3	86.0	85.63	85.81

Sensory Evaluation (9 point Hedonic Scale)

	2016-17	2017-18	Pooled
M1	5.67	5.27	5.47
M2	7.77	7.0	7.38
M3	8.10	8.03	8.06

TSS (^{o}Brix)

	2016-17	2017-18	Pooled
M1	4.50	4.67	4.58
M2	5.33	5.33	5.33
M3	7.0	6.83	6.91

Vitamin-C (mg/100g)

	2016-17	2017-18	Pooled
M1	45.20	53.67	49.43
M2	68.80	77.38	73.09
M3	92.80	108.42	100.61

Capsaicin(µg/g)

	2016-17	2017-18	Pooled
M1	16,843	16,771	16,807
M2	20,746	18,362	19,554
M3	21,737	23,815	22,776

Plate.1(a): Samples prior to treatment

Plate.1(b): Treated samples for storage and analysis

higher moisture content in green stage and lower in red/ripe stage is in agreement with the results of Martinez *et al*., 2005, Borah, 2003) & Bhagawati, 2009. The amount of moisture is dependent on the age and type of pods harvested. The content differs at various stages of fruit development as stated by Howalder *et al*., 1996. The fruit dehydrates, begin to turn colour and deteriorates within a few days after harvest in ambient condition (Wall and Berghage, 2007).

Packaging materials (P)

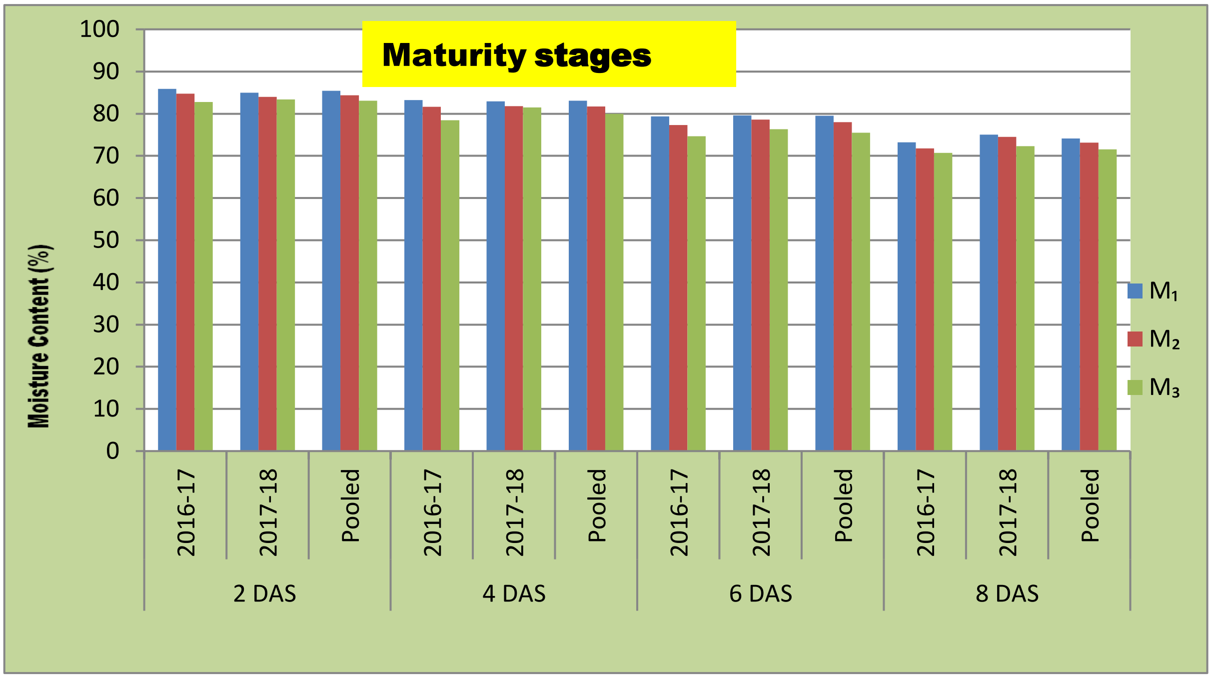
The effect of packaging materials on the moisture content is presented in Table 4.1. The packaging materials had significantly influenced the moisture content on all dates of observation during both the years of observation as well as in the pooled data analysis. In general, the moisture content decreased gradually with storage time irrespective of the packaging materials. The loss of moisture during the present study may be due to the ripening process that undergo throughout the storage period as ripening of pepper fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Goodwin and Mercer 1972; Suslow 2000; Antoniali *et al*., 2007. The present finding of a decreasing trend in the moisture content with storage time is in agreement with the finding of Samira *et al*., 2013 who recorded a general decreasing trend in the moisture content of some hot pepper varieties with storage time under both ambient and evaporative storage conditions. In the first year, the highest moisture content was recorded in banana leaf (76.76%), while in the second year the highest was recorded in perforated polythene (78.23%). However, in pooled data, banana leaf gave the highest moisture content (77.22%). The lowest moisture content was recorded in newspaper during both the years of observation as well as in pooled data (66.84%, 69.61%, 68.22%) respectively on the final date of observation. The high moisture levels recorded in the banana leaf and perforated polythene packaging could be due to creating a barrier around the fruit and did not allow enough water loss from the fruits as compared to other packaging systems because the modified atmosphere packaging (MAP) technique consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration and reduce moisture loss. The control fruits and newspaper packed fruits offered low protection to the fruits and therefore allowed rapid water loss from the fruits to the surrounding air as Jobling (2001) in his studies reported that the air movement over the produce was a highly significant factor in determining the rate of moisture loss.

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation throughout the experiment. However, the highest was recorded in M_1P_3 (78.43%) while the lowest in M_3P_1 (67.06%).

Table 4.1: Influence of maturity stages and packaging materials on moisture content (%) of Naga king chilli

Treatments	Days After Storage											
	2 DAS			4 DAS			6 DAS			8 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Maturity stages (M)												
M_1	85.88	84.96	85.42	83.22	82.96	83.09	79.37	79.62	79.50	73.22	75.02	74.12
M_2	84.75	84.02	84.38	81.63	81.81	81.72	77.33	78.63	77.98	71.74	74.49	73.11
M_3	82.76	83.41	83.09	78.44	81.46	79.95	74.64	76.31	75.47	70.74	72.33	71.53
SEm±	0.02	61.10	0.07	0.06	59.66	0.11	0.03	60.57	0.07	0.06	57.29	0.11
CD at 5%	**0.08**	**NS**	**0.24**	**0.23**	**NS**	**0.40**	**0.10**	**NS**	**0.24**	**0.23**	**NS**	**0.35**
Packaging materials (P)												
P_0	82.40	83.33	82.86	78.55	81.09	79.82	73.85	76.14	75.00	67.81	70.26	69.03
P_1	82.15	83.06	82.60	77.87	80.67	79.26	72.73	75.71	74.22	66.84	69.61	68.22
P_2	86.54	85.04	85.79	84.01	83.23	83.62	80.96	80.62	80.79	76.20	78.23	77.21
P_3	86.79	85.07	85.93	83.97	83.31	83.64	80.92	80.27	80.59	76.76	77.68	77.22
Sem±	0.04	0.18	0.09	0.05	0.20	0.11	0.04	0.10	0.06	0.08	0.15	0.07
CD at 5%	**0.13**	**0.59**	**0.32**	**0.16**	**0.68**	**0.37**	**0.13**	**0.33**	**0.19**	**0.28**	**0.51**	**0.24**
Interaction (M×P)												
M_1P_0	83.60	83.81	83..70	80.15	81.97	81.06	76.14	77.92	77.03	69.25	71.73	70.49
M_1P_1	83.15	83.58	83.36	79.26	81.25	80.25	74.20	77.40	75.80	67.81	70.77	69.29
M_1P_2	88.20	86.17	87.18	86.30	84.22	85.26	83.06	81.68	82.37	77.60	78.97	78.28
M_1P_3	88.60	86.28	87.44	87.20	84.40	85.80	84.10	81.50	82.80	78.24	78.63	78.43
M_2P_0	82.30	83.17	82.73	79.30	80.55	79.92	74.15	76.77	75.46	67.40	70.76	69.08
M_2P_1	82.12	82.91	82.51	78.52	80.50	79.51	73.34	76.39	74.86	66.53	70.14	68.33
M_2P_2	87.20	85.06	86.13	84.50	82.98	83.74	81.27	80.92	81.09	76.20	78.86	77.53
M_2P_3	87.41	84.93	86.17	84.23	83.23	83.73	80.56	80.46	80.51	76.82	78.19	77.50
M_3P_0	81.30	83.02	82.16	76.21	80.80	78.50	71.27	73.75	72.51	66.80	68.30	67.55
M_3P_1	81.15	82.72	81.93	75.83	80.26	78.04	70.68	73.36	72.02	66.20	67.92	67.06
M_3P_2	84.24	83.91	84.07	81.24	82.48	81.86	78.50	79.26	78.88	74.82	76.87	75.84
M_3P_3	84.37	84.01	84.19	80.50	82.31	81.40	78.12	78.86	78.49	75.15	76.24	75.69
SEm±	0.02	0.10	0.06	0.06	0.09	0.06	0.04	0.12	0.09	0.06	0.16	0.09
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**



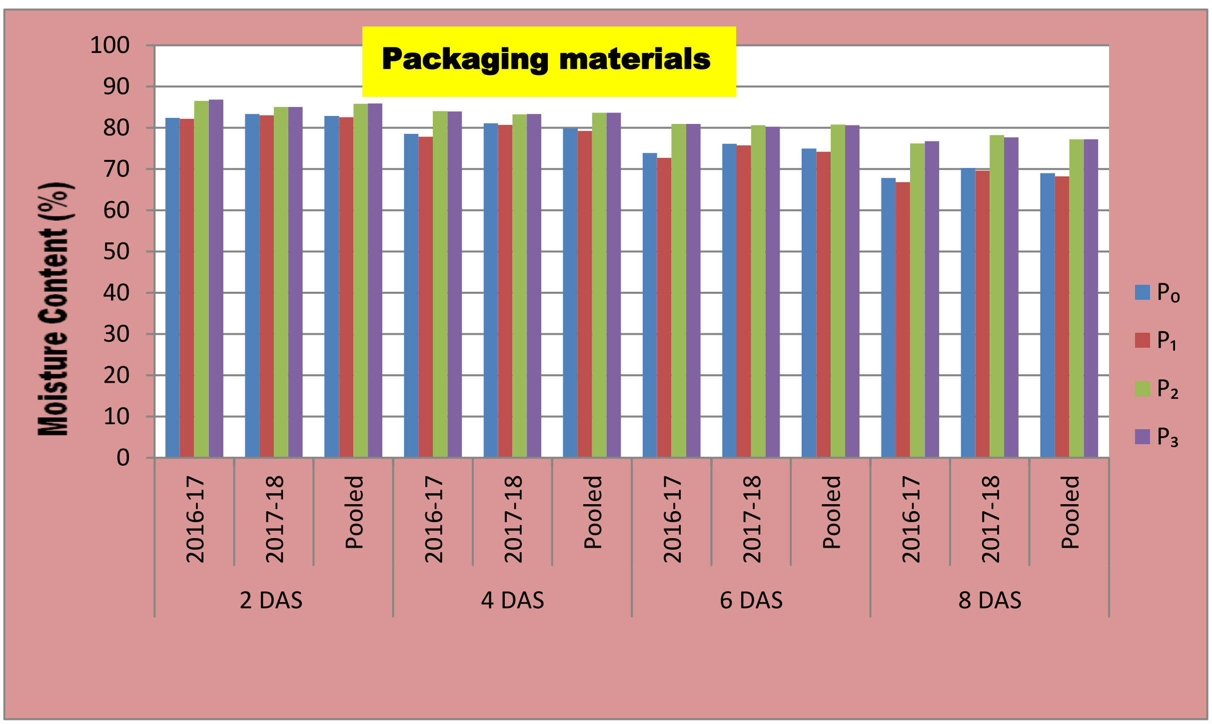


Figure.4. 1: Influence of maturity stages and Packaging materials on Moisture (%) of Naga King Chilli

4.1.2. Rotting (%)

Maturity stages (M)

Table 4.2. presents the effect of maturity stages on the rotting percentage of fruits. The maturity stages showed significant effect till 2nd day in the first year, 6th day onwards in the second year and till 4th day in the pooled data. The rotting percentage increased with the storage time irrespective of the treatments. The matured green fruits have started rotting only from the 4^{th} day while in case of turning and red stage the rotting started from 2^{nd} day itself though it was higher in red stage. In both the years of observation as well as in pooled data, it was observed that the red stage (M_3) showed the highest rotting % (27.49%,23.33%, 25.41%) while the matured green stage (M_1) showed the lowest rotting % (17.49%, 15.0%, 16.24%) respectively on the last date of observation. The higher decay or rotting (%) in red/ripe stage may be because of higher rate of respiration, more skin permeability for water loss and high susceptibility to decay organism. This finding is supported by the findings of Goojing *et al*., 1999; Moneruzzaman *et al*., 2008 and Moniruzzamani *et al*., 2015.

Packaging materials (P)

Table 4.2. presents the effect of packaging materials on the rotting percentage of fruits. In the first year, the packaging treatments showed significant influence from the 6^{th} day onwards while, in the second year, it did not show significant effect. However, in the pooled data analysis, the packaging treatments showed significant influence from the 6^{th} day onwards. The rotting percentage increased with the storage time irrespective of the treatments. In both the years of observation as well as in pooled data, it was observed that the perforated polythene (P_2) showed the highest rotting % (27.77%, 24.43%, 26.10%) while newspaper (P_1) showed the lowest rotting % (14.44%, 13.33%, 13.88%) respectively on the last date of observation. In the present study, the fruits kept in perforated

polyethylene bags and banana leave had more decay than fruits kept in the paper and the control. The perforated polyethylene and banana leaf inhibited fruit senescence by reducing water loss which leads to the accumulation of moisture in and around the produce that favours post-harvest decay (Coates *et al.*, 1995), hence more rotting percentage recorded. Lower rotting incidence in the paper packed and control fruits could be attributed to proper air circulation thereby reducing the amount of moisture accumulated on the fruit surface, hence created an unfavourable environment for growth of decay pathogens. Ceponis *et al*., (1987) reported that the storage life of pepper fruit was limited by pathological deterioration. Incidence of fruit decay was recorded in the film-packed fruits, but not in the control (Edusei, 2011).

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation throughout the experiment. However, the highest was recorded in M_3P_2 (31.66%) and lowest in M_1P_1 (8.33%).

Table 4.2: Influence of maturity stages and packaging materials on rotting (%) of Naga king chilli

Treatments	Days After Storage											
	2 DAS			4 DAS			6 DAS			8 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Maturity stages (M)												
M_1	0.00	0.00	0.00	3.33	3.33	3.33	6.66	6.66	6.66	17.49	15.00	16.24
M_2	4.99	3.33	4.16	8.32	8.33	8.32	12.49	10.83	11.66	22.49	19.16	20.82
M_3	6.66	8.33	7.49	11.66	12.50	12.08	15.83	18.33	17.08	27.49	23.33	25.41
SEm±	1.31	1.49	0.70	1.54	1.75	1.02	1.32	1.58	2.29	1.52	3.25	1.86
CD at 5%	**4.69**	**NS**	**2.53**	**NS**	**NS**	**3.71**	**NS**	**5.75**	**NS**	**NS**	**11.81**	**NS**
Packaging materials (P)												
P_0	5.55	4.40	4.90	12.21	11.10	11.65	19.99	15.53	17.76	23.33	19.96	21.64
P_1	1.11	2.20	1.65	4.44	5.50	4.97	5.55	7.73	6.64	14.44	13.33	13.88
P_2	4.44	5.50	4.97	7.77	8.83	8.30	12.21	13.30	12.75	27.77	24.43	26.10
P_3	4.44	3.30	3.87	6.66	6.63	6.64	8.88	11.10	9.99	24.44	18.86	21.65
SEm±	1.13	1.44	1.13	1.80	1.78	1.74	1.54	1.78	1.39	1.98	3.03	1.90
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**6.88**	**NS**	**4.66**	**5.96**	**NS**	**6.36**
Interaction (M×P)												
M_1P_0	0.00	0.00	0.00	6.66	6.66	6.66	16.66	10.00	13.33	20.00	13.33	16.66
M_1P_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	1.66	10.00	6.66	8.33
M_1P_2	0.00	0.00	0.00	3.33	3.33	3.33	6.66	6.66	6.66	23.33	20.00	21.66
M_1P_3	0.00	0.00	0.00	3.33	3.33	3.33	3.33	6.66	4.99	16.66	16.66	16.66
M2P_0	6.66	3.33	4.99	13.33	10.00	11.66	20.00	13.33	16.66	23.33	20.00	21.66
M_2P_1	0.00	0.00	0.00	6.66	6.66	6.66	6.66	6.66	6.66	13.33	13.33	13.33
M_2P_2	6.66	6.66	6.66	6.66	10.00	8.33	13.33	13.33	13.33	26.66	23.33	24.99
M_2P_3	6.66	3.33	4.99	6.66	6.66	6.66	10.00	10.00	10.00	26.66	20.00	23.33
M_3P_0	10.00	10.00	10.00	16.66	16.66	16.66	23.33	23.33	23.33	26.66	23.33	24.99
M_3P_1	3.33	6.66	4.99	6.66	10.00	8.33	10.00	13.33	11.66	20.00	20.00	20.00
M_3P_2	6.66	10.00	8.33	13.33	13.33	13.33	16.66	20.00	18.33	33.33	30.00	31.66
M_3P_3	6.66	6.66	6.66	10.00	10.00	10.00	13.33	16.66	14.99	30.00	23.33	26.66
SEm±	0	0	0	1.44	1.44	1.44	1.44	1.44	1.44	1.86	2.04	1.95
CD at 5%	**0**	**0**	**0**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.1.3. Sensory evaluation (9-point Hedonic scale)

Maturity stages (M)

The effect of different maturity stages on sensory evaluation of Naga king chilli fruits is depicted in Table 4.3. The data reveals that the maturity stages significantly influenced the sensory evaluation in both the year as well as in the polled data analysis. During both the years of experiment as well as in pooled data, initially the red stage (M_3) obtained the highest score while matured green (M_1) scored the lowest. The scoring gradually decreased with the increase in storage time, irrespective of the maturity stages. In the first year of experiment, the highest (6.14) and lowest (5.44) were scored from matured green (M_1) and red stage (M_3) respectively. However, in the second year and pooled data, the highest (5.75 & 5.91) was scored in turning (M_2) and lowest (5.3 & 5.47) in matured green stage (M_1) respectively on the last date of observation. Consumer acceptance of vegetables is highly dependent on appearance and flavour (Rocha *et al*., 2013). In the present study, the initial highest score was obtained from the red stage but with the increase in storage time the table reveals that on the last date of observation (8^{th} day) the turning stage scored the highest which is due to the fact that it has reached the red stage with fully developed red colour on that day while the red staged fruit has become unacceptable due to dehydration, rotting and shriveling on the 8^{th} day that resulted with the lowest score.

Packaging materials (P)

Table 4.3. presents the effect of packaging materials on sensory evaluation of Naga king chilli fruits. The packaging materials had significantly influenced the moisture during both the years of observation as well as in the pooled data analysis (except in the first year on 2^{nd} day of observation). The table reveals that

in both the years of experiment as well as in the pooled data analysis, it was observed that banana leaf packaging (P_3) recorded the highest score (6.13, 5.79 & 5.96) and the control fruits (P_0) recorded the lowest sensory score (5.47, 5.16 & 5.32) respectively on the last date of observation. The fruit packed in banana leaf and perforated polythene bags scored higher than the newspaper packaging and controlled fruits which may be due to lesser loss of moisture and therefore appeared fresher. The banana leaf and perforated polythene served as a barrier to moisture loss resulting in high RH with a better quality of the fruits with low percentage of shriveled fruits. This finding is supported by the result of Samira et al. (2013) who stated that the increased RH in the cooler reduces shrinkage of fruits through moisture loss which is a major cause for decline in percent marketability. Meir et al., (1995) also reported that using plastic materials such as polyethylene bag packaging was a useful in maintaining the postharvest quality of the pepper fruits as it prevents water loss and fruit softening.

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation throughout the experiment. However, the highest sensory evaluation was scored in M_2P_3 (6.16) and lowest in M_3P_0 (4.90) on the last day of observation.

Table 4.3: Influence of maturity stages and packaging materials on sensory evaluation (9 point hedonic scale) of Naga king chilli

Treatments	Days After Storage											
	2 DAS			4 DAS			6 DAS			8 DAS		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Maturity stages (M)												
M_1	5.73	5.54	5.63	6.98	5.62	6.24	6.76	5.41	6.08	6.14	5.30	5.72
M_2	7.88	7.10	7.48	7.81	7.17	7.49	7.38	6.96	7.17	6.08	5.75	5.91
M_3	8.07	7.97	8.01	7.95	8.09	8.02	6.71	6.74	6.72	5.44	5.51	5.47
SEm±	0.07	0.05	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
CD at 5%	**0.26**	**0.18**	**0.17**	**0.10**	**0.08**	**0.08**	**0.07**	**0.09**	**0.07**	**0.07**	**0.05**	**0.04**
Packaging materials (P)												
P_0	7.11	6.69	6.90	7.44	6.75	7.10	6.60	6.12	6.36	5.47	5.16	5.32
P_1	7.23	6.78	7.01	7.53	6.85	7.19	6.84	6.24	6.54	5.96	5.43	5.69
P_2	7.27	6.94	7.11	7.62	7.04	7.33	7.14	6.45	6.79	5.97	5.70	5.83
P_3	7.35	7.06	7.21	7.72	7.20	7.46	7.23	6.65	6.94	6.13	5.79	5.96
SEm±	0.10	0.04	0.06	0.02	0.02	0.01	0.03	0.03	0.03	0.03	0.02	0.02
CD at 5%	**NS**	**0.13**	**NS**	**0.07**	**0.07**	**0.04**	**0.11**	**0.09**	**0.09**	**0.09**	**0.05**	**0.05**
Interaction (M×P)												
M_1P_0	5.50	5.33	5.41	6.83	5.37	5.87	6.50	5.17	5.83	5.80	5.07	5.43
M_1P_1	5.60	5.47	5.53	6.90	5.53	6.21	6.60	5.27	5.93	6.03	5.20	5.61
M_1P_2	5.83	5.63	5.73	7.00	5.73	6.36	6.83	5.47	6.15	6.23	5.43	5.83
M_1P_3	6.00	5.73	5.86	7.20	5.87	6.53	7.10	5.73	6.41	6.50	5.50	6.00
M_2P_0	7.83	6.87	7.35	7.70	6.97	7.33	7.04	6.63	6.83	5.83	5.43	5.63
M_2P_1	7.83	7.00	7.41	7.80	7.03	7.41	7.40	6.77	7.08	6.0	5.60	5.80
M_2P_2	7.90	7.17	7.53	7.83	7.23	7.53	7.50	7.10	7.30	6.20	5.93	6.06
M_2P_3	7.93	7.37	7.65	7.90	7.47	7.68	7.60	7.33	7.46	6.30	6.03	6.16
M_3P_0	8.00	7.87	7.93	7.80	7.93	7.86	6.20	6.57	6.38	4.80	5.00	4.90
M_3P_1	8.03	7.90	7.96	7.90	8.00	7.95	6.53	6.70	6.61	5.87	5.50	5.68
M_3P_2	8.10	8.03	8.06	8.03	8.17	8.10	7.10	6.80	6.95	5.50	5.73	5.61
M_3P_3	8.13	8.10	8.11	8.07	8.27	8.17	7.00	6.90	6.95	5.60	5.83	5.71
SEm±	0.09	0.02	0.06	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.01
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.1.4. Shelf life (days)

Maturity stages (M)

Table 4.4. depicts the effect of different maturity stages on shelf life of Naga king chilli fruits. In the present study, in both the years of experiment as well in the pooled data analysis, the maturity stages had significantly influenced the shelf life where the highest was recorded from matured green stage *i.e.*, M_1 (7.50, 7.58 & 7.54 days) followed by turning stage *i.e.*, M_2 (6.75, 6.91 & 6.83 days) and lowest from red stage *i.e.*, M_3 (4.91, 4.83 & 4.87 days) respectively. The present finding is in agreement with Hossain *et al*., 1996; Moneruzzaman *et al*., 2008 and Moniruzzamani *et al*., 2015 who recorded the maximum shelf life in mature green tomatoes followed by half ripe and minimum in full ripe tomatoes. Samira *et al*. 2013 also reported that the quality characters were maintained better when harvested at mature green stage. They mentioned that rotting in pepper fruits were major causes for a decline in percent marketability with time, which is the reason with the red stage fruits in the present study that recorded the highest rotting percentage leading to shorter shelf life than the other maturity stages because shelf life refers to the end of consumer acceptability, and is the time at which majority of consumers are displeased with the product (Labuza and Schmidl, 1985). The storage life of pepper fruit was also limited by pathological deterioration (Ceponis *et al*., 1987). Fresh chillies losses water very quickly after harvest and begin to wrinkle and change colour within a few days without refrigerated storage. Diaz-Perez *et al*., (2007) also in their shelf life studies concluded that rapid water loss was a major determinant of fruit shelf life.

Packaging materials (P)

The effect of packaging materials on the shelf life is presented in Table 4.4. In both the years of experiment as well in the pooled data analysis, the packaging materials had significantly influenced the shelf life of the fruits where the highest was recorded from newspaper packaging *i.e*., P_1 (7.78, 7.67 & 7.72 days) followed by banana leaf *i.e*., P_3 (6.78, 7.11 & 6.94 days) and the lowest from control *i.e*., P_0 (4.44, 4.78 & 4.61 days) respectively. The naga king chilli fruit is a highly perishable vegetable with a short shelf-life. The present study found that the packaged fruits had a longer shelf life than the control. This is in agreement with the result of Singh *et al*. (2014) who examined shelf-life enhancement of green bell pepper (*Capsicum annuum* L.) under active modified atmosphere storage and reported that the shelf life of bell pepper was extended to 49 days in active packages and 42 days with MA packages, as compared to 7 days with non-packed controlled samples at ambient conditions. Chitravathi *et al*. (2015) also reported a shelf life of 16, 18, 22 and 28 days in chillies packed in microporous, PE-LD, polyolefin and anti-fog films, respectively, as compared to 15 days in the case of control samples. The storage life of pepper fruit was limited by pathological deterioration Ceponis *et al*., 1987. Diaz-Perez *et al*., (2007) also in their shelf life studies concluded that rapid water loss was a major determinant of fruit shelf life. But in the present study, the paper packed fruits had the highest shelf life though it had the highest moisture loss which may be due to lesser rotting incidence as compared to other treatments that resulted in a longer period of marketability. This may be inferred that the rotting parameter has more effect on the marketability of Naga king chilli than the moisture parameter.

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation throughout the experiment. However, the highest shelf life was recorded from M_1P_1 (9.16 days) and lowest from M_3P_0 (3.16 days).

Plate 3 (a). Influence of maturity stages and packaging materials at 4 DAS

Plate 3(b). Influence of maturity stages and packaging materials at 6 DAS

Table 4.4: Influence of maturity stages and packaging materials on shelf life (Days) of Naga king chilli

Treatments	Days		
	2016-17	**2017-18**	**Pooled**
Maturity stages (M)			
M_1	7.50	7.58	7.54
M_2	6.75	6.91	6.83
M_3	4.91	4.83	4.87
SEm±	0.11	0.16	0.12
CD at 5%	**0.38**	**0.57**	**0.43**
Packaging materials (P)			
P_0	4.44	4.78	4.61
P_1	7.78	7.67	7.72
P_2	6.55	6.22	6.38
P_3	6.78	7.11	6.94
Sem±	0.16	0.10	0.09
CD at 5%	**0.53**	**0.34**	**0.31**
Interaction (M×P)			
M_1P_0	5.33	5.67	5.50
M_1P_1	9.00	9.33	9.16
M_1P_2	7.67	7.00	7.33
M_1P_3	8.00	8.33	8.16
M_2P_0	5.00	5.33	5.16
M_2P_1	8.33	8.00	8.16
M_2P_2	6.67	7.00	6.83
M_2P_3	7.00	7.33	7.16
M_3P_0	3.00	3.33	3.16
M_3P_1	6.00	5.67	5.83
M_3P_2	5.33	4.67	5.00
M_3P_3	5.33	5.67	5.50
SEm±	0.12	0.14	0.08
CD at 5%	**NS**	**NS**	**NS**

4.1.5. Total Soluble Solids (TSS ^{o}Brix)

Maturity stages (M)

The effect of different maturity stages on TSS content of Naga king chilli fruits are depicted in Table 4.5. The maturity stages had significantly influenced the TSS content in both the year as well as in the pooled data analysis on all dates of observation (except on the last day *i.e.*, 8th day in the first year). The TSS content of matured green fruit increased with the storage time. While in case of turning stage it increased up to 6th day then declined. In case of red stage, it increased up to 4th day then declined. The initial TSS content was found lowest in matured green stage **(**M_1) followed by turning stage (M_2) and highest in red stage (M_3) in both the experiment as well as in the pooled data analysis. But on the last day of observation, in the first year, the highest (7.25) and lowest (7.04) TSS content were recorded from red (M_3) and matured green stage (M_1) respectively. While in the second year and pooled data analysis, the highest (7.04 & 7.04) and lowest (5.92 & 6.58) were recorded from matured green (M_1) and red stage (M_3) respectively. Therefore it could be accepted that the matured green had the highest and red stage had the lowest TSS content.

Sweetness in bell pepper appeared to be typical for ripe stages and closely related to glucose, fructose, total sugar, and dry matter content (Luning *et al*., 1994). It is well known that sugars and simple acids are respiration substrates, and the longer the time of fruit respiration, the higher will be the rates of consumption of sugars and acids (Atta-Aly and Brecht, 1995). The polysaccharides of the cell wall are broken up with a consequent increase in sugar levels during ripening (Antoniali *et al*., 2007). As the fruit ripens more of its cell walls and structures are degraded to provide energy for its respiratory activities. The result of the present study is similar with the findings of Howalder *et al*., (1996), Gorny and Kader

(1998), Lee *et al*. (1999), Borah (2003) and Tamilmani (2005) who reported an increase in the amount of soluble solids as fruits ripen and decreased once senescence was reached. The decrease in soluble solids in turning and red stage might be due to the respiration of the chilli fruits which consumed the soluble solids as reported by Wills *et al.*, (1981).

Packaging materials (P)

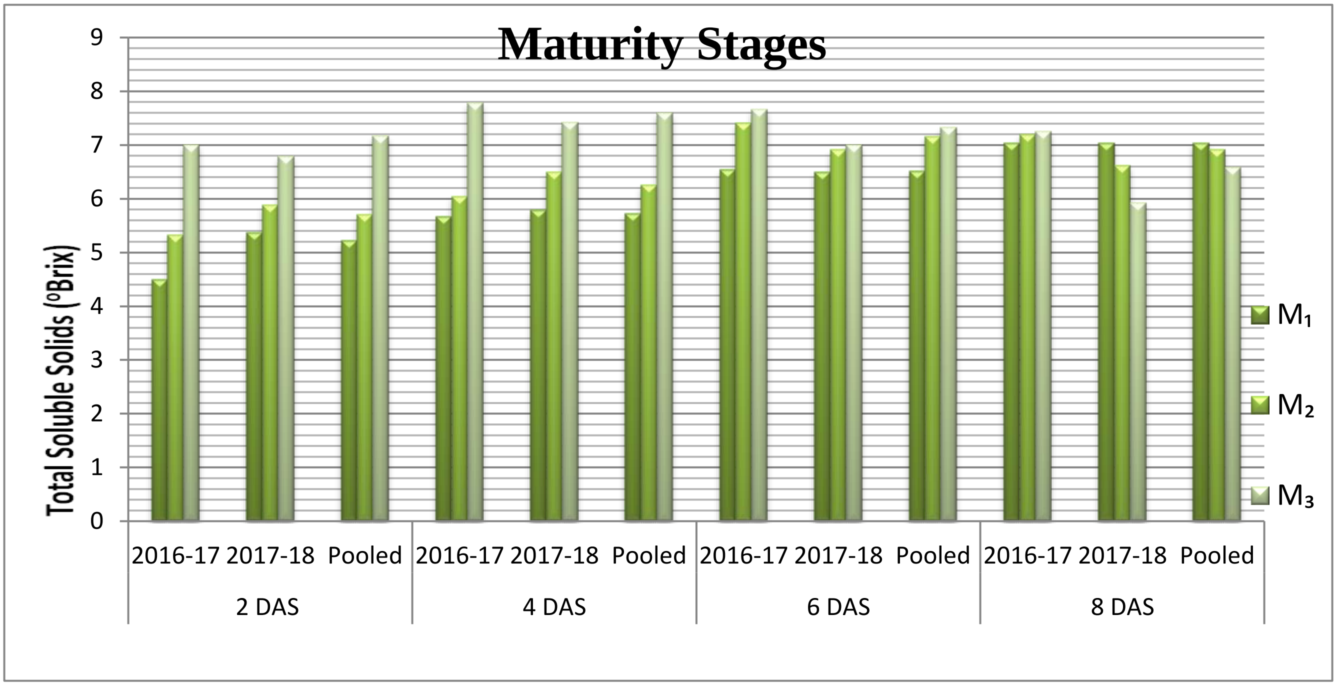
Table 4.5. presents the effect of packaging materials on the TSS content of fruits. The packaging materials had significantly influenced the TSS content on most dates of observation in both the years of observation as well as in the pooled data. The data reveals that it gradually increased up to 6th day then declined irrespective of the packaging treatments. Initial increase in TSS content up to 6th day could potentially be attributed to moisture loss by the fruits and conversion of organic acids to sugars (Samira *et al*., 2013). The reduction in the TSS content in the later period might probably be due to it being used as a respiratory substrate during the metabolic process (Kays, 1991). This decreasing trend is often related to the components used as energy partly to carry on respiration and other metabolic functions (Latifah *et al*., 2008). On the last day of observation, the TSS content was found highest in newspaper packaging *i.e*., P_1 (7.67, 7.08 & 7.27) and lowest in perforated polythene packaging *i.e*., P_2 (6.72, 6.28 & 6.50) in both the years of observation as well as in the pooled data respectively. The higher TSS content in newspaper packaging might be due to increased moisture loss from the fruits thereby increasing the concentration of TSS content compared to other treatments that had higher R.H.

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation. However, the highest TSS content was recorded from M_1P_1 (7.75) and lowest from M_3P_2 (6.33).

Table 4.5: Influence of maturity stages and packaging materials on Total Soluble Solids (ºBrix) of Naga king chilli

Treatments	Days After Storage											
	2 DAS			4 DAS			6 DAS			8 DAS		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Maturity stages (M)												
M_1	4.50	5.37	5.22	5.67	5.79	5.72	6.54	6.50	6.52	7.04	7.04	7.04
M_2	5.33	5.88	5.71	6.04	6.50	6.26	7.41	6.91	7.16	7.20	6.62	6.91
M_3	7.00	6.79	7.17	7.78	7.42	7.59	7.66	7.00	7.33	7.25	5.92	6.58
SEm±	0.06	0.11	0.07	0.06	0.07	0.06	0.05	0.07	0.05	0.09	0.06	0.05
CD at 5%	**0.23**	**0.38**	**0.26**	**0.23**	**0.27**	**0.20**	**0.17**	**0.27**	**1.70**	**NS**	**0.21**	**0.17**
Packaging materials (P)												
P_0	6.27	6.17	6.22	6.67	6.67	6.67	7.55	6.77	7.16	7.50	6.77	6.99
P_1	6.44	6.44	6.44	6.83	6.94	6.88	7.61	7.08	7.34	7.67	7.08	7.37
P_2	5.94	5.72	5.82	6.33	6.33	6.33	6.88	6.61	6.74	6.72	6.28	6.50
P_3	5.78	5.72	5.75	6.16	6.33	6.24	6.84	6.61	6.72	6.77	6.61	6.60
Sem±	0.08	0.10	0.06	0.10	0.06	0.06	0.05	0.11	0.06	0.07	0.07	0.05
CD at 5%	**0.26**	**0.34**	**0.20**	**0.34**	**0.20**	**0.20**	**0.18**	**NS**	**NS**	**0.22**	**0.24**	**0.18**
Interaction (M×P)												
M_1P_0	5.33	5.33	5.33	5.83	6.00	5.91	7.00	6.50	6.75	7.66	7.00	7.33
M_1P_1	5.50	5.83	5.66	6.00	6.33	6.16	7.00	7.00	7.00	7.83	7.67	7.75
M_1P_2	4.83	5.17	5.00	5.50	5.50	5.50	6.17	6.17	6.17	6.50	6.67	6.58
M_1P_3	4.66	5.17	4.91	5.33	5.33	5.33	6.00	6.33	6.16	6.17	6.83	6.50
M_2P_0	5.83	6.00	5.69	6.16	6.50	6.33	7.83	6.83	7.33	7.50	6.50	7.00
M_2P_1	6.00	6.17	6.08	6.50	6.83	6.66	8.00	7.17	7.58	7.67	6.83	7.25
M_2P_2	5.50	5.67	5.58	5.83	6.33	6.08	7.00	6.83	6.91	6.67	6.50	6.58
M_2P_3	5.33	5.67	5.50	5.66	6.33	5.99	6.83	6.83	6.83	7.00	6.67	6.83
M_3P_0	7.60	7.17	7.38	8.00	7.50	7.75	7.83	7.00	7.41	7.33	6.00	6.66
M_3P_1	7.83	7.33	7.58	8.00	7.67	7.83	7.83	7.17	7.50	7.50	6.17	6.83
M_3P_2	7.50	6.33	6.91	7.60	7.17	7.38	7.50	7.17	7.33	7.00	5.67	6.33
M_3P_3	7.33	6.33	6.83	7.50	7.33	7.41	7.50	6.67	7.08	7.17	5.83	6.50
SEm±	0.07	0.08	0.07	0.06	0.06	0.04	0.04	0.06	0.05	0.07	0.07	0.03
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**



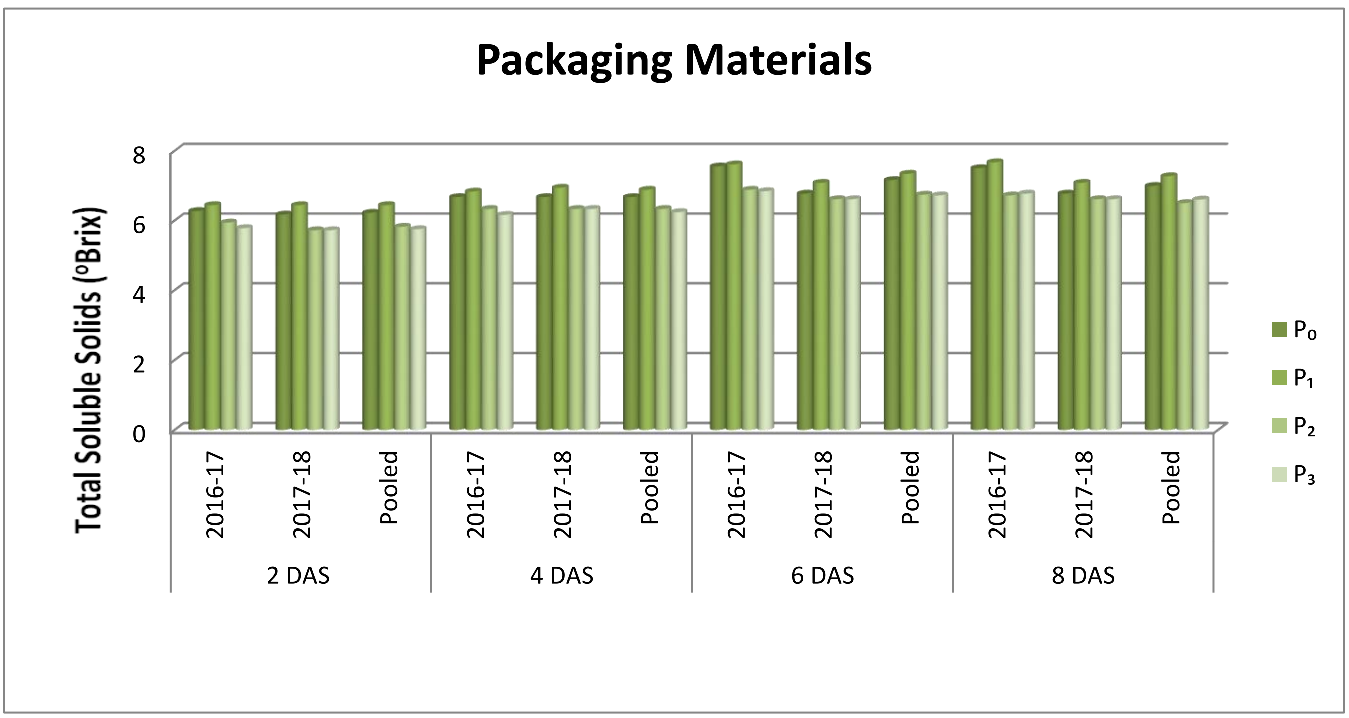


Figure 4.5: Influence of Maturity stages and Packaging materials on Total Soluble Solids (ºBrix) of Naga King Chilli

4.1.6. Vitamin C (mg/100g)

Maturity stages (M)

Table 4.6. depicts the effect of different maturity stages on vitamin C content of Naga king chilli fruits. The maturity stages had significantly influenced the vitamin C content on all dates of observation in both the year as well as in the pooled data analysis. Initially, it was lowest in matured green stage (M_1) and highest in red stage (M_3) in both the experiment as well as in the pooled data analysis. Climatic conditions including light and average temperature have a strong influence on the chemical composition of horticultural crops (Klein and Perry, 1982) which could be the reason for noticeable difference in vitamin-C content between first and second year. In general, the lower the light intensity during growth, the lower the AA content of plant tissues (Harris, 1975). In the present study, the vitamin C content was initially found higher in the red stage as compared to turning and lowest in matured green stage which is similar with the findings of Hawaldar and Hossain, (1997) and Robi and Sreelathakumary, (2004). The data from the table reveals that the vitamin C content increased gradually with the increase in storage time in matured green stage (M_1). While in turning stage (M_2) it increased up to 6th day then declined from 8th day. In case of red stage (M_3) it decreased gradually with the increase in storage time. In both the years of experiment as well as in the pooled data, the turning stage (M_2) showed the highest vitamin C content (74.40, 92.93 & 83.66) and red stage (M_3) showed the lowest (66.0, 75.42 & 68.91) respectively on the last date of observation. The present finding of gradual increase in ascorbic acid content from green to red ripening while, decreased in the lateral stages is agreed according to the data reported by Howard *et al*. (1994), Osuna- Garcia *et al*., (1998), Martinez *et al*.,

(2005), Kumar *et al*. ,(2009) and Samira *et al*., (2013). The loss of ascorbic acid may be due to water loss which increased oxidation (Nunes *et al.,* 1998).

Packaging materials (P)

Table 4.6. presents the effect of packaging materials on the vitamin C content. The packaging materials had significantly influenced the vitamin C content in both the years of observation as well as in the pooled data. In control (P_0) and newspaper packaging (P_1) it gradually increased up to 6th day, then decreased. While, in case of perforated polythene (P_2) and banana leaf packaging (P_3) it kept increasing till the last day of observation. The gradual increase in vitamin C content is because after harvest, the commodity is still living as it continues to perform metabolic reactions in order to maintain its physiological system. The data from the table reveals that it start decreasing from the 8th day in case of control and newspaper packaging. This may be due to the reason that once the fruit is harvested the source of organic compounds for its energy comes from its own reserves. These reserves are depleted by the respiration process causing a decrease in the quality of the commodity (Kays, 1991; Maguire *et al*., 2004). However, in case of banana leaf and perforated polythene packaging, it kept increasing till the last day of observation which may be due to the reason that MAP retarded respiration, ripening, and senescence and inhibit oxidative reactions which requires free oxygen (Leistner and Gould, 2002). In both the years of observation as well as in the pooled data, the vitamin C content was found highest in banana leaf *i.e*., P_3 (70.40, 85.83 & 78.11) and lowest in control *i.e*., P_0 (64.80, 77.79 & 71.29) on the last day of observation respectively. The control and newspaper packed fruits have reached the senescence earlier than the banana leaf and perforated polythene packed fruits which may be due to better protection by the later packaging materials in a way that it provided lower temperature and

higher relative humidity around the fruits which could have retarded or delayed the senescence process because ascorbic acid losses are accelerated at higher temperatures (Lee and Kader, 2000 and Samira *et al*., 2013) and rapid water loss in case of control and paper packed fruits might have enhanced the loss of ascorbic acid because of increased oxidation (Nunes *et al.*, 1998).

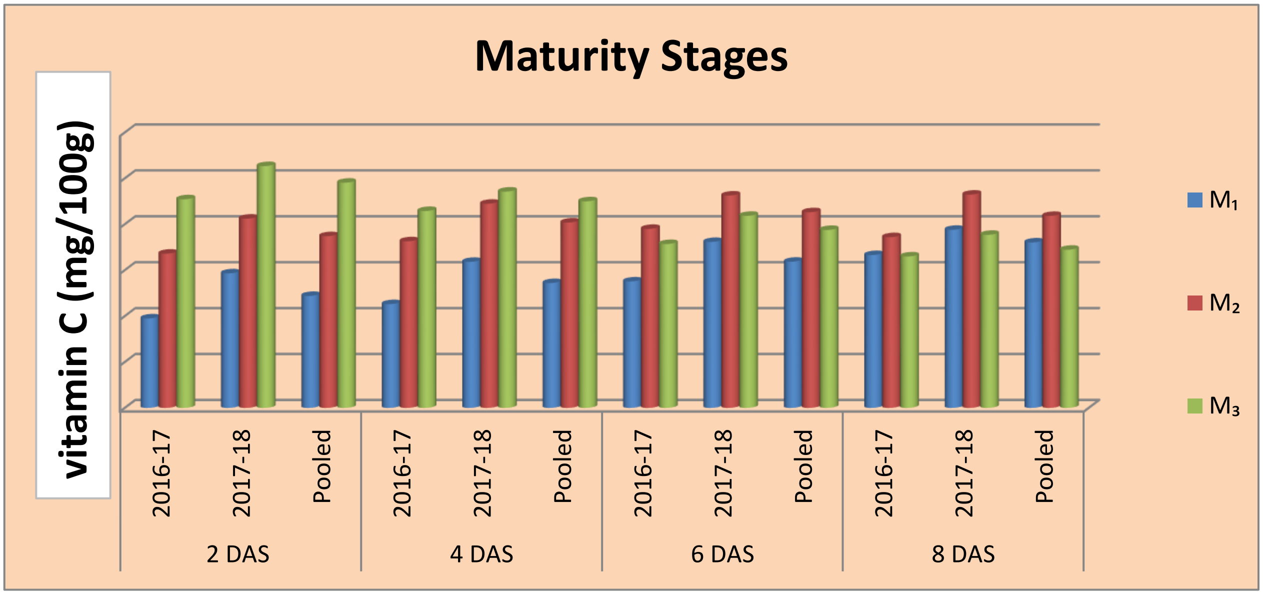
Interaction

The interaction between the maturity stages and packaging materials was significant in most dates of observation in the second year. But not significant in the first year and pooled data analysis. However, the highest vitamin C was recorded from M_2P_3 (88.43) and lowest from M_3P_0 (63.76)

Plate 4 : Influence of maturity stages and packaging materials at 8 DAS

Table 4.6: Influence of maturity stages and packaging materials on vitamin C content (mg/100g) of Naga king chilli

Treatments	Days After Storage											
	2 DAS			4 DAS			6 DAS			8 DAS		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Maturity stages (M)												
M_1	39.00	58.63	48.80	45.22	63.63	54.40	55.10	72.31	63.70	66.60	77.61	72.10
M_2	67.20	82.47	74.83	72.60	88.96	80.78	78.00	92.53	85.26	74.40	92.93	83.66
M_3	90.90	105.36	98.13	85.80	94.25	90.02	71.40	83.69	77.54	66.00	75.42	68.91
SEm±	0.31	0.16	0.20	0.32	0.06	0.15	0.31	0.20	0.13	0.40	0.18	0.24
CD at 5%	**1.13**	**0.57**	**0.74**	**1.15**	**0.21**	**0.56**	**1.11**	**0.74**	**0.49**	**1.44**	**0.65**	**0.89**
Packaging materials (P)												
P_0	66.80	83.41	75.10	68.80	82.59	75.69	69.60	82.55	76.07	64.80	77.79	71.29
P_1	65.20	82.75	73.97	70.86	82.81	76.84	67.60	83.12	75.35	65.20	79.97	72.58
P_2	65.60	81.14	73.37	67.20	81.71	74.45	68.53	82.17	75.35	70.40	84.34	77.36
P_3	65.20	81.29	73.24	67.60	81.99	74.78	67.20	83.52	75.36	70.40	85.83	78.11
SEm±	0.49	0.24	0.27	1.58	0.11	0.77	0.31	0.18	0.19	0.43	0.08	0.23
CD at 5%	**NS**	**0.81**	**0.89**	**NS**	**0.35**	**2.59**	**1.04**	**0.60**	**NS**	**1.43**	**0.28**	**0.78**
Interaction (M×P)												
M_1P_0	40.80	60.27	50.53	48.00	65.09	56.54	58.80	75.06	66.93	67.20	76.24	71.72
M_1P_1	39.60	58.35	48.97	47.50	64.61	56.05	55.20	73.62	64.41	68.40	77.18	72.79
M_1P_2	38.40	57.81	48.10	43.20	62.24	52.72	54.00	69.99	61.99	64.80	78.08	71.44
M_1P_3	37.20	58.08	47.62	42.00	62.59	52.29	52.40	70.58	61.49	66.00	78.93	72.46
M_2P_0	69.60	85.80	77.70	75.60	92.09	83.84	80.40	94.16	87.28	68.40	88.42	78.41
M_2P_1	67.20	84.81	76.00	74.40	91.60	83.00	79.20	94.67	86.93	69.60	90.97	80.28
M_2P_2	66.00	79.56	72.78	69.60	85.94	77.77	76.80	90.27	83.53	79.20	95.85	87.52
M_2P_3	66.00	79.73	72.86	70.80	86.20	78.50	75.60	91.01	83.30	80.40	96.47	88.43
M_3P_0	90.00	104.21	97.10	82.80	90.60	86.70	69.60	78.45	74.02	58.80	68.72	63.76
M_3P_1	88.80	105.10	96.95	81.60	92.24	86.92	68.40	81.07	74.73	57.60	71.77	64.68
M_3P_2	92.40	106.07	99.23	88.80	96.97	92.88	74.40	86.26	80.33	67.20	79.09	73.14
M_3P_3	92.40	106.07	99.23	90.00	97.19	93.59	73.20	88.97	81.08	66.00	82.11	74.05
SEm±	0.42	0.09	0.29	0.40	0.08	0.23	0.42	0.15	0.27	0.30	0.16	0.16
CD at 5%	**NS**	**0.26**	**NS**	**NS**	**0.22**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.46**	**NS**



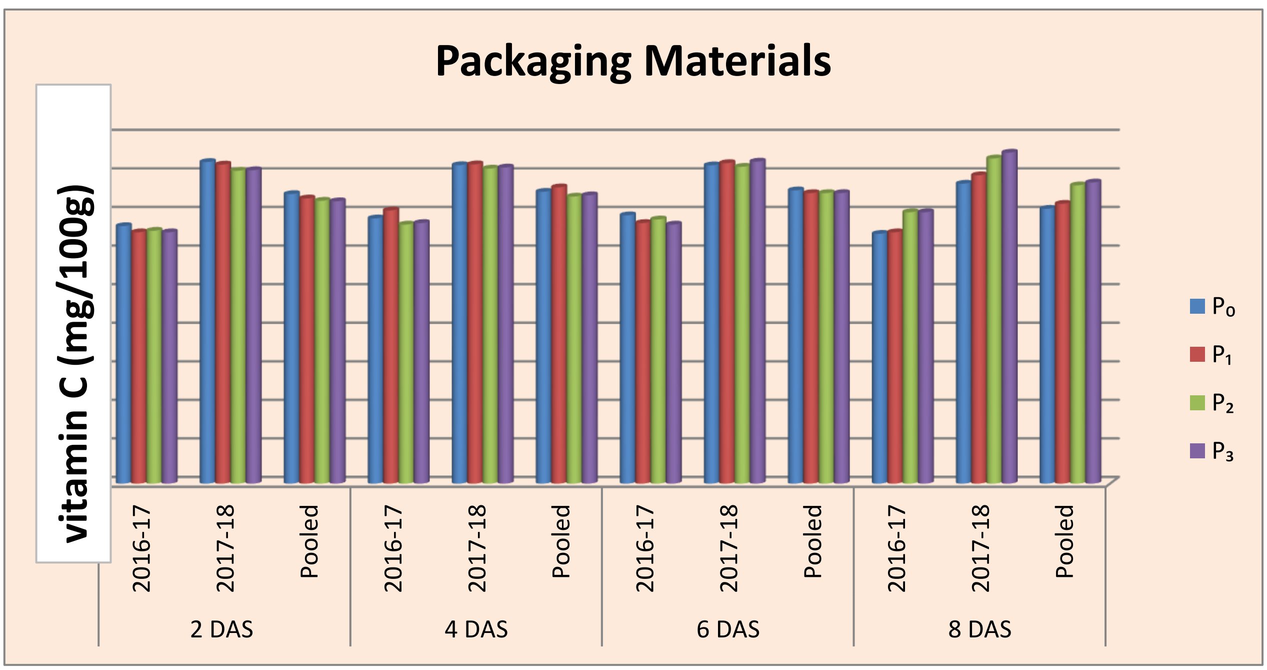


Figure 4.2 : Influence of maturity stages and Packaging materials on vitamin C (mg/100g) of Naga King Chilli

4.1.7. Capsaicin (μg/g)

Maturity stages (M)

The effect of maturity stages on capsaicin content is depicted in Table 4.7. The maturity stages had significantly influenced the capsaicin content of the fruits. During both the years of experiment as well as in pooled data analysis, the capsaicin content was found highest in red stage (M_3) followed by turning (M_2) and lowest in matured green stage (M_1). The increase in capsaicinoids content with fruit maturation may be related to increased dry matter content (Ahmed *et al*., 1996 and Sheela, 1998). This result is also similar with the findings of Mini and Wahab, (2002), Robi and Sreelathakumary, (2004) and Pandey *et al*., (2010) but against the finding of Buczkowska *et al*. 2013 who reported that the highest amount of capsaicinoids (capsaicin and dihydrocapsaicin) in fruits harvested at the initial stage of maturity, green fruits (on average 309 mg/kg) compared to fruits turning colour (258 mg/kg) and red fruits (250 mg/kg). In the first year, all the three stages (matured green=16,138.50, turning=19,919.75 & red=20,217.50) showed a slight decrease on the 6th day as compared to the initial reading (matured green=16,843, turning=20,746 & red=21,737). However, in the second year and pooled data, the capsaicin content of matured green has increased from 16,771 to 18,405 and 16,807.17 to 17,272.0 and in turning it has increased from 18,361 to 20,196.75 and 19,553.50 to 20,058.25 respectively. While in red stage, it has decreased from 23,815 to 21,900.25 and 22,776.33 to 21,058.87 respectively on the last day of observation *i.e.*, 6th day as compared to the initial reading. The present finding of higher capsaicin content in matured green and turning stage on the 6th day as compared to initial reading is similar with the finding of Samira *et al*., 2013 who reported that capsaicin % was more at 12th day as compared to at harvest. The capsaicin content in the present study varied from 1.67 to 2.38%

which is similar with the finding of Mena *et al*., 2018 who evaluated capsaicin content in *Bhut jolokia* genotypes from North East India and recorded a capsaicin content of 0.75-4.65 %.

Packaging materials (P)

The effect of packaging materials on capsaicin content is presented in Table 4.7. The data from the table reveals that the packaging materials had significant influence on the capsaicin content of Naga king chilli fruits during both the experimental years as well as in the pooled data. Generally, it decreased with storage time in all the treatments. However, in both the experimental years as well as in the pooled data, the highest was recorded from newspaper packaging *i.e.***,** P_1 (19,380.0, 21,306.67 & 20,343.33) and lowest from perforated polythene packaging *i.e*., P_2 (17,936.67, 19,171.0 & 18,557.17) respectively. It is assumed that peroxidases catalyze capsaicinoid oxidation and plays a central role in its metabolism in pepper (Yu *et al*., 2005). In the present study, it was found that the capsaicin content was highest in paper packaging followed by control. This may be due to higher rate of moisture loss from the fruit (as compared to perforated polythene and banana leaf packaging) because peroxidase activity is lower in fruits which have low moisture content (Bernal and Barcelo, 1996). Lower peroxidase and capsaicin oxidase activity means that the oxidation, or breakdown, of capsaicin will be slower when fruits have low moisture. Thus, both higher rates of synthesis and lower rates of degradation could also contribute to the greater concentration of capsaicin in fruits with low moisture content (Gibbis and O'Garro, 2004; Yu *et al*., 2005). It may be mentioned that the banana leaf and perforated polythene packaging materials might have provided a better modified atmosphere surrounding the fruits with a lower temperature and higher relative humidity thus resulting in a warmer temperature in the paper packed and controlled fruits which might have resulted in a higher capsaicin content. This finding is supported by the findings of Sathiyamurthy *et al*., 2002 who reported that the increasing concentration of capsaicinoids under warmer temperature than at lower temperature might be due to faster ripening as well as loss in moisture content of the fruits. Samira *et al*., 2013 also reported that high capsaicin content (2.3%) was observed in peppers subjected to ambient storage conditions than in those stored in the evaporative cooler.

Interaction

The interaction between the maturity stages and packaging materials was not significant on all dates of observation throughout the experiment. However, the highest was recorded from M_3P_1 (22,005.0) and lowest from M_1P_2 (16,560.0).

Table 4.7: Influence of maturity stages and packaging materials on capsaicin content (µg/g) of Naga king chilli

Treatments	Day -6		
	2016-17	**2017-18**	**Pooled**
Maturity stages (M)			
M_1	16,138.50	18,405.50	17,272.00
M_2	19,919.75	20,196.75	20,058.25
M_3	20,217.50	21,900.25	21,058.87
SEm±	109.85	100.87	45.39
CD at 5%	**399.34**	**366.70**	**165.00**
Packaging materials (P)			
P_0	19,037.00	20,589.67	19,813.33
P_1	19,380.00	21,306.67	20,343.33
P_2	17,936.67	19,171.00	18,557.17
P_3	18,680.66	19,596.00	19,138.33
SEm±	165.45	90.81	107.96
CD at 5%	**509.81**	**279.81**	**332.67**
Interaction (M×P)			
M_1P_0	16,523.00	18,429.00	17,476.00
M_1P_1	16,517.00	19,843.00	18,180.00
M_1P_2	15,238.00	17,882.00	16,560.00
M_1P_3	16,276.00	17,468.00	16,872.00
M_2P_0	20,196.00	21,051.00	20,623.50
M_2P_1	20,348.00	21,342.00	20,845.00
M_2P_2	19,243.00	18,827.00	19,035.00
M_2P_3	19,892.00	19,567.00	19,729.50
M_3P_0	20,392.00	22,289.00	21,340.50
M_3P_1	21,275.00	22735.00	22,005.00
M_3P_2	19,329.00	20,824.00	20,076.50
M_3P_3	19,874.00	22,735.00	20,813.50
SEm±	169.59	88.05	107.83
CD at 5%	**NS**	**NS**	**NS**

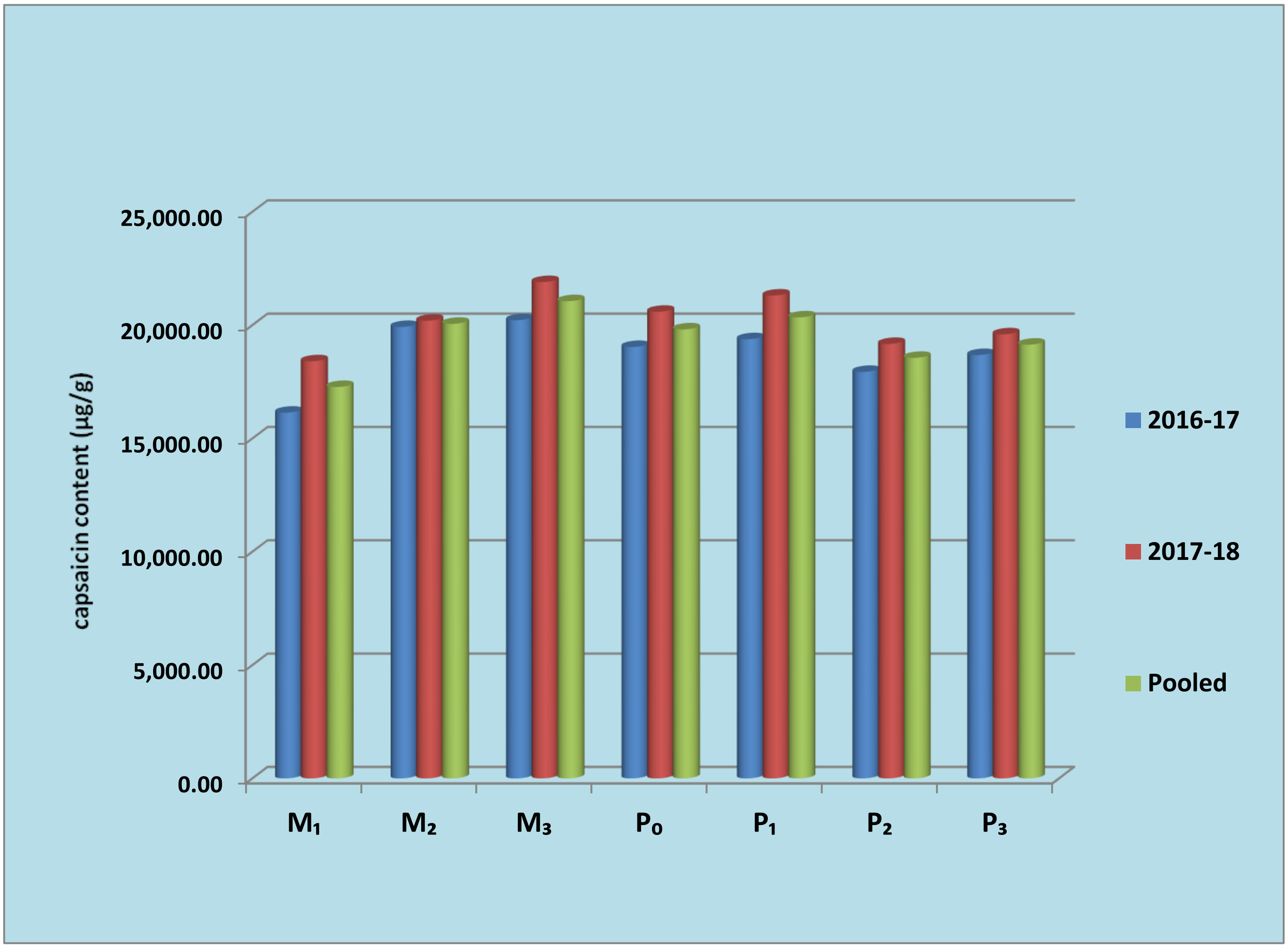


Figure 4.3 : Influence of Maturity stages and Packaging materials on Capsaicin content (µg/g) of Naga king chilli

4.2. Influence of different maturity stages on quality and shelf life of different processed products prepared from Naga king chilli.

4.2.1. Sensory evaluation (9-point Hedonic scale)

Whole dried pod (V_1)

The influence of maturity stages on sensory evaluation of whole dried pod of Naga king chilli is presented in Table 4.8. The data from the table reveals that the maturity stages had significant influence on the sensory evaluation on all dates of observation during both the experimental years (2016-17 & 2017-18) and also during the analysis of pooled data. The sensory score gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the years of experiment as well as in pooled data, at 0 day (after the product development), the red stage (M_3) scored the highest (7.60, 7.40 & 7.50) followed by turning stage i.e., M_2 (6.0, 6.13 & 6.07) while matured green stage (M_1) scored the lowest (5.60, 5.27 & 5.43). However, on the last day of observation i.e., 120th day, these scores were reduced to (6.30, 6.20 & 6.25) in red stage, (5.20, 5.33 & 5.27) in turning and (4.10, 3.60&3.85) in matured green stage respectively.

Paste (V_2)

The influence of maturity stages on sensory evaluation of naga king chilli paste is presented in Table 4.8. The data from the table reveals that the maturity stages had significant influence on the sensory evaluation on all dates of observation during both the experimental years and also in the pooled data. However, it gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the experimental years and also in the pooled data, at 0 day (after the product development), the red stage **(**M_3) scored the highest (8.0, 8.07 & 8.03) followed by turning stage i.e., M_2 (7.20, 7.43 & 7.32)

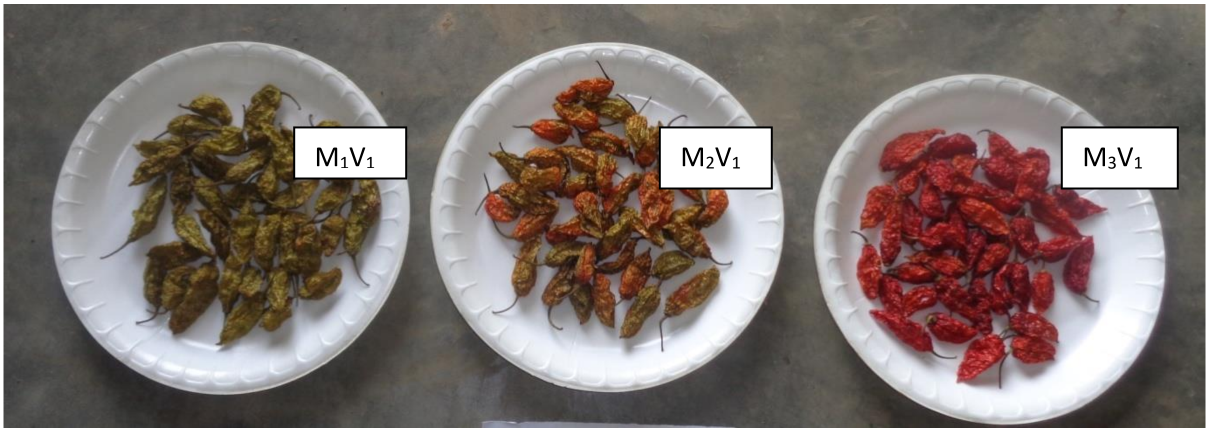


Plate 5(a). Appearance of whole dried pod of different maturity stages at 0 day

Plate 5(b). Appearance of paste of different maturity stages at 0 day

Plate 5(c). Appearance of powder of different maturity stages at 0 day

while matured green stage (M_1) scored the lowest (7.0, 6.63 & 6.82). However, on the last day of observation i.e., 120th day, these scores were reduced to (6.10, 6.03 & 6.07) in red stage, (6.10, 5.73 & 5.92) in turning and (4.20, 4.03 & 4.12) in matured green stage respectively.

Powder (V_3)

The influence of maturity stages on sensory evaluation of Naga king chilli powder is presented in Table 4.8. The data from the table reveals that the maturity stages had significant influence on the sensory evaluation on all dates of observation during both the experimental year and also in the pooled data. However, it gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the experimental years and also in the pooled data, at 0 day (after the product development), the red stage (M_3) scored the highest (7.80, 7.20 & 7.50) followed by turning stage i.e., M_2 (5.80, 5.47 & 5.63) while matured green stage (M_1) scored the lowest (5.10, 4.83 & 4.97). However, on the last day of observation *i.e.*, 120th day, these scores were reduced to (6.60, 6.40 & 6.50) in red stage, (6.40, 4.30 & 5.35) in turning and (4.30, 3.77 & 4.03) in matured green stage respectively.

The most important quality of a chilli, next to pungency, is colour. Dried chilli is a spice product and the one most widely used as condiments for flavouring and colouring in Asian cuisines (Toontom *et al.*, 2010). The market value of chilli lies in its colour, both surface and extractable colour. Colour retention is influenced by storage temperature and moisture content (Malchey *et al.*, 1982). The quality of dried chilli is assessed by a number of different parameters such as colour, hotness, ascorbic acid content and volatile flavour compounds (Kim *et al.*, 2006; Wang *et al.*, 2009; Yaldiz *et al.*, 2010). Drying is one of the common preservative methods for bell pepper. Drying lowers water activity which increases shelf life of the product, reduces the storage volume and decreases transport costs (Ade-Omowaye *et al*., 2003; Vega *et al*., 2007). However, the thermal processing of pepper affects the physic-chemical qualities of the final product (Kolawole and Olaniyi 2010; Raji *et al*., 2010). The data from the present study reveals that all the products developed from red stage scored highest during the sensory evaluation. This may be due to more acceptance or liking by the judges for the appealing red coloured product coupled with better aroma as compared to turning and matured green stage products because consumer acceptance of vegetables is highly dependent on appearance and flavour as reported by Rocha *et al*., (2013).

Bosland and Votava, 2012; Gomez-Garcia and Ochoa-Alejo, 2013 also reported that the amount of carotenoids is important for the quality of dried chili pepper powders. This may also be another reason for higher sensory score by the products developed from red stage fruits as compared to turning and matured greenstage.

Table 4.8: Influence of maturity stages on sensory evaluation (9 point hedonic scale) of different processed products prepared from Naga king chilli

Treatments	Days After Storage														
	0 DAYS			**30 DAYS**			**60 DAYS**			**90 DAYS**			**120 DAYS**		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Whole dried pod															
V_1M_1	5.60	5.27	5.43	5.40	5.03	5.22	5.00	4.53	4.77	4.60	4.17	4.38	4.10	3.60	3.85
V_1M_2	6.00	6.13	6.07	5.80	6.03	5.92	5.50	5.63	5.57	5.20	5.40	5.30	5.20	5.33	5.27
V_1M_3	7.60	7.40	7.50	7.50	7.10	7.30	7.30	7.03	7.17	7.10	6.73	6.92	6.30	6.20	6.25
SEm±	0.09	0.04	0.05	0.13	0.04	0.08	0.06	0.03	0.03	0.05	0.03	0.03	0.07	0.05	0.05
CD at 5%	**0.33**	**0.15**	**0.17**	**0.45**	**0.15**	**0.26**	**0.20**	**0.12**	**0.12**	**0.16**	**0.09**	**0.09**	**0.26**	**0.18**	**0.17**
Paste															
V_2M_1	7.00	6.63	6.82	6.70	6.23	6.47	6.10	5.73	5.92	5.30	5.13	5.22	4.20	4.03	4.12
V_2M_2	7.20	7.43	7.32	7.10	7.23	7.17	6.90	7.00	6.95	6.40	6.47	6.43	6.10	5.73	5.92
V_2M_3	8.00	8.07	8.03	8.0	8.03	8.02	7.60	7.77	7.68	7.20	7.03	7.12	6.10	6.03	6.07
SEm±	0.10	0.05	0.06	0.09	0.03	0.06	0.10	0.03	0.05	0.06	0.03	0.04	0.06	0.05	0.03
CD at 5%	**0.35**	**0.16**	**0.22**	**0.31**	**0.12**	**0.19**	**0.35**	**0.09**	**0.19**	**0.20**	**0.12**	**0.13**	**0.20**	**0.16**	**0.10**
Powder															
V_3M_1	5.10	4.83	4.97	5.00	4.37	4.68	4.80	4.17	4.48	4.40	3.80	4.10	4.30	3.77	4.03
V_3M_2	5.80	5.47	5.63	5.60	5.30	5.45	5.60	5.13	5.37	5.30	4.77	5.03	6.40	4.30	5.35
V_2M_3	7.80	7.20	7.50	7.60	7.03	7.32	7.50	6.83	7.17	7.20	6.63	6.92	6.60	6.40	6.50
SEm±	0.10	0.03	0.05	0.08	0.03	0.04	0.09	0.03	0.05	0.06	0.03	0.03	0.05	0.04	0.03
CD at 5%	**0.35**	**0.09**	**0.19**	**0.28**	**0.09**	**0.14**	**0.31**	**0.12**	**0.16**	**0.20**	**0.09**	**0.09**	**0.16**	**0.13**	**0.09**

4.2.2. Shelf life (days)

Whole dried pod (V_1)

The influence of maturity stages on shelf life of whole dried pod is presented in Table 4.9. The data from the table reveals that the maturity stages had significant influence on the shelf life on all dates of observation in both the experimental years and as well as in the pooled data where the turning stage (M_2) gave the highest shelf life (166.67, 162.67 & 164.67) followed by matured green stage *i.e.*, M_1 (165.0, 152.67 & 158.83) while red stage (M_3) gave the lowest shelf life (152.0, 143.67 & 147.83) respectively.

Paste (V_2)

The influence of maturity stages on shelf life of paste is presented in Table 4.9. The data from the table reveals that the maturity stages had significant influence on the shelf life of paste on all dates of observation during both the experimental years and also in the pooled data where the red stage (M_3) gave the highest shelf life (140.67, 133.33 & 137.0) followed by turning stage *i.e.*, M_2 (134.0, 126.0 & 130.0) while matured green stage M_1 gave the lowest shelf life (128.33, 122.33 & 125.33) respectively.

Powder (V_3)

The influence of maturity stages on the shelf life of powder is presented in Table 4.9. The data from the table reveals that the maturity stages did not reach significance level in the first year but in the second year and pooled data it showed significant influence on the shelf life on all dates of observation where the red stage (M_3) gave the highest shelf life (186.0, 190.0 & 188.0) followed by turning stage *i.e.*, M_2 (185.0, 188.67 & 186.83) while matured green stage M_1 gave the lowest shelf life (183.33, 177.0 & 180.17) respectively.

Shelf life refers to the end of consumer acceptability, and is the time at which majority of consumers are displeased with the product (Labuza and Schmidl, 1985). Off shaped but high quality bell pepper are available in the local market, which are non-marketable due to their appearance. This type of commodities could be subjected to minimal processing and be sold at local supermarkets as a value added products (Ediriweera *et al*., 2014) which can be achieved by developing natural paste because the thermal processing of pepper affects the physic-chemical qualities of the final product (Kolawole and Olaniyi 2010; Raji *et al*., 2010) in case of whole dried pods and powder. The data from the present study reveals that the whole dried pod developed from turning stage had highest shelf life followed by matured green stage. The lowest shelf life of red stage may be due to more dry rotting incidence which was not seen in other two stages. However, discolouration and darkening with the increase in storage time was observed in all the three products. But in case of both paste and powder the highest shelf life was recorded from red stage which may be due to better colour and aroma as compared to the other two products though discolouration and darkening was seen in all the three products because shelf life refers to the end of consumer acceptability, and is the time at which majority of consumers are displeased with the product (Labuza and Schmidl, 1985) and consumer acceptance of vegetables is highly dependent on appearance and flavour as reported by Rocha *et al*., 2013.

Plate 6(a): Appearance of whole dried pod of different maturity stages after 6 months

Plate 6(b): Appearance of paste of different maturity stages after 6 months

Plate 6(c): Appearance of powder of different maturity stages after 6

Table 4.9: Influence of Maturity stages on shelf life of different processed products prepared from Naga king chilli

Treatments	Days		
	2016-17	**2017-18**	**Pooled**
Whole dried pod			
V_1M_1	165.00	152.67	158.83
V_1M_2	166.67	162.67	164.67
V_1M_3	152.00	143.67	147.83
SEm±	2.43	1.29	1.28
CD at 5%	**8.42**	**4.47**	**4.43**
Paste			
V_2M_1	128.33	122.33	125.33
V_2M_2	134.00	126.00	130.00
V_2M_3	140.67	133.33	137.00
SEm±	1.04	1.23	0.77
CD at 5%	**3.59**	**4.26**	**2.66**
Powder			
V_3M_1	183.33	177.00	180.17
V_3M_2	185.00	188.67	186.83
V_2M_3	186.00	190.00	188.00
SEm±	35.55	1.64	1.76
CD at 5%	**NS**	**5.69**	**6.09**

4.2.3. Vitamin C (mg/100g)

Whole dried pod (V_1)

The influence of maturity stages on vitamin C content of whole dried pod is presented in Table 4.10. The data from the table reveals that the maturity stages had significant influence on vitamin C content on all dates of observation during both the experimental years as well as in the pooled data. However, it gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the years of observation as well as in the pooled data, at 0 day (after the product development), the highest vitamin C (65.27, 75.60 & 70.43) was recorded from red stage (M_3) followed by (60.87, 63.46 & 62.16) from turning stage (M_2) and lowest (36.30, 41.95 & 39.13) from matured green stage (M_1). However, on the last day of observation *i.e.*, 120th day, it was reduced to (34.83, 42.09 & 38.46) in red stage, (31.92, 34.20 & 33.06) in turning stage and (17.79, 21.96 & 19.88) in matured green stage respectively.

Paste (V_2)

The influence of maturity stages on vitamin C content of paste is presented in Table 4.10. The data from the table reveals that the maturity stages had significant influence on vitamin-C content on all dates of observation during both the experimental years as well as in the pooled data. However, it gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the years of observation as well as in the pooled data, at 0 day (after the product development), the highest vitamin C (92.0, 92.06 & 92.03) was recorded from red stage (M_3) followed by (74.40, 78.80 & 76.60) from turning stage (M_2) and lowest (46.40, 48.53 & 47.47) from matured green stage (M_1). However, on the last day of observation *i.e.*, 120th day, it was reduced to (59.63, 58.53 & 59.08) in red stage, (49.23, 52.88 & 51.05) in turning stage and (31.20, 34.20 & 32.70) in matured green stage respectively.

Powder (V_3)

The influence of maturity stages on vitamin C content of powder is presented in Table 4.10. The data from the table reveals that the maturity stages had significant influence on vitamin C content on all dates of observation during both the experimental years as well as in the pooled data. However, it gradually decreased with the storage time irrespective of the different maturity stages treatments. In both the years of observation as well as in the pooled data, at 0 day (after the product development), the highest vitamin C (62.33, 71.04 & 66.69) was recorded from red stage (M_3) followed by (58.67, 61.20 & 59.93) from turning stage (M_2) and lowest (35.20, 40.67 & 37.94) from matured green stage (M_1). However, on the last day of observation *i.e.*, 120th day, it was reduced to (31.95, 35.85 & 33.90) in red stage, (28.97, 30.13 & 29.55) in turning stage and (15.79, 16.99 & 16.39) in matured green stage respectively.

The data from the Table shows that the vitamin C content was found to be highest in red stage in all the three different value added products. This may be due to the difference in the initial content itself where red stage had the highest followed by turning stage and lowest in matured green stage. Processing methods and cooking procedures can result in significant losses of vitamin C (Fennema, 1977). The present study shows that the content of vitamin-C in the dried pod and powder has significantly reduced after the product development from the first day of observation (0 day) in all the experiment. This may be due to detrimental effect of the heated air during drying that inherently exposes the products to oxidation, thus reducing the ascorbic acid content (Vega-Galvez *et al.*, 2008). This finding is in good agreement with the results of: Howard *et al.*, (1994) who reported that

75% of ascorbic acid in red chilli was lost during drying; the content in dried fruits is degraded to residual levels of only 10% or less (Ramesh *et al*., 2001); dehydration of peppers resulted in an 88% decrease in ascorbic acid content (Martinez *et al*., 2005); the ascorbic acid contents of all dried chilli varied between 14.21 and 51.55 mg/100g , whereas, it was 53.19 mg/100g in fresh chilli (Toontom *et al*. 2012) and Reis *et al*., 2013 who evaluated the effect of drying temperature on the nutritional and antioxidant qualities of cumari peppers from Para (*Capsicum chinense* Jacqui) found that the content of vitamin C for the dried pepper differed significantly ($P < 0.05$) compared with the fresh pepper as the micronutrients (ash and vitamin C), together with the phenolic compounds, capsaicin and antioxidant activity, were degraded by the use of high temperatures.

The present data also reveals that the vitamin C content in paste did not significantly reduced on the first day of observation (0 day) after the product development. This may be due to the reason that it did not undergo heating and drying treatment. However, the content decreased with the increase in storage time.

Table 4.10 : Influence of Maturity stages on vitamin C content (mg/100 g)of different processed products prepared from Naga king chilli

Treatments	Days After Storage														
	0 DAYS			30 DAYS			60 DAYS			90 DAYS			120 DAYS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Whole dried pod															
V_1M_1	36.30	41.95	39.13	32.40	38.62	35.51	29.52	35.81	32.67	24.98	29.61	27.30	17.79	21.96	19.88
V_1M_2	60.87	63.46	62.16	55.44	57.75	56.59	51.12	51.81	51.46	45.07	44.35	44.71	31.92	34.20	33.06
V_1M_3	65.27	75.60	70.43	60.84	68.60	64.72	56.88	63.02	59.95	48.53	55.33	51.93	34.83	42.09	38.46
SEm±	0.70	0.08	0.37	0.46	0.27	0.32	0.72	0.13	0.40	0.57	0.45	0.40	0.16	0.31	0.15
CD at 5%	**2.43**	**0.27**	**1.28**	**1.61**	**0.92**	**1.10**	**2.49**	**0.45**	**1.39**	**1.96**	**1.55**	**1.40**	**0.56**	**1.08**	**0.52**
Paste															
V_2M_1	46.40	48.53	47.47	41.23	45.60	43.41	38.16	41.44	39.80	35.28	37.03	36.15	31.20	34.20	32.70
V_2M_2	74.40	78.80	76.60	68.96	72.55	70.76	61.56	66.86	64.21	56.52	59.86	58.19	49.23	52.88	51.05
V_2M_3	92.0	92.06	92.03	82.99	82.44	82.71	74.16	73.15	73.66	68.40	66.19	67.29	59.63	58.53	59.08
SEm±	0.65	0.26	0.33	0.11	0.24	0.15	0.69	0.40	0.36	0.62	0.26	0.25	0.90	0.18	0.50
CD at 5%	**2.26**	**0.88**	**1.13**	**0.38**	**0.85**	**0.53**	**2.39**	**1.37**	**1.25**	**2.16**	**0.92**	**0.87**	**3.10**	**0.64**	**1.74**
Powder															
V_3M_1	35.20	40.67	37.94	31.32	35.85	33.59	27.36	30.78	87.21	23.57	25.74	24.66	15.79	16.99	16.39
V_3M_2	58.67	61.20	59.93	54.36	55.89	55.12	49.12	50.36	49.74	42.29	43.45	42.87	28.97	30.13	29.55
V_2M_3	62.33	71.04	66.69	59.04	66.27	62.66	52.56	59.56	56.06	47.15	53.16	50.15	31.95	35.85	33.90
SEm±	0.60	0.31	0.32	0.59	0.22	0.31	0.61	0.37	0.43	0.60	0.38	0.41	0.21	0.12	0.05
CD at 5%	**2.07**	**1.08**	**1.11**	**2.03**	**0.75**	**1.09**	**2.11**	**1.28**	**1.49**	**2.08**	**1.32**	**1.42**	**0.71**	**0.41**	**0.19**

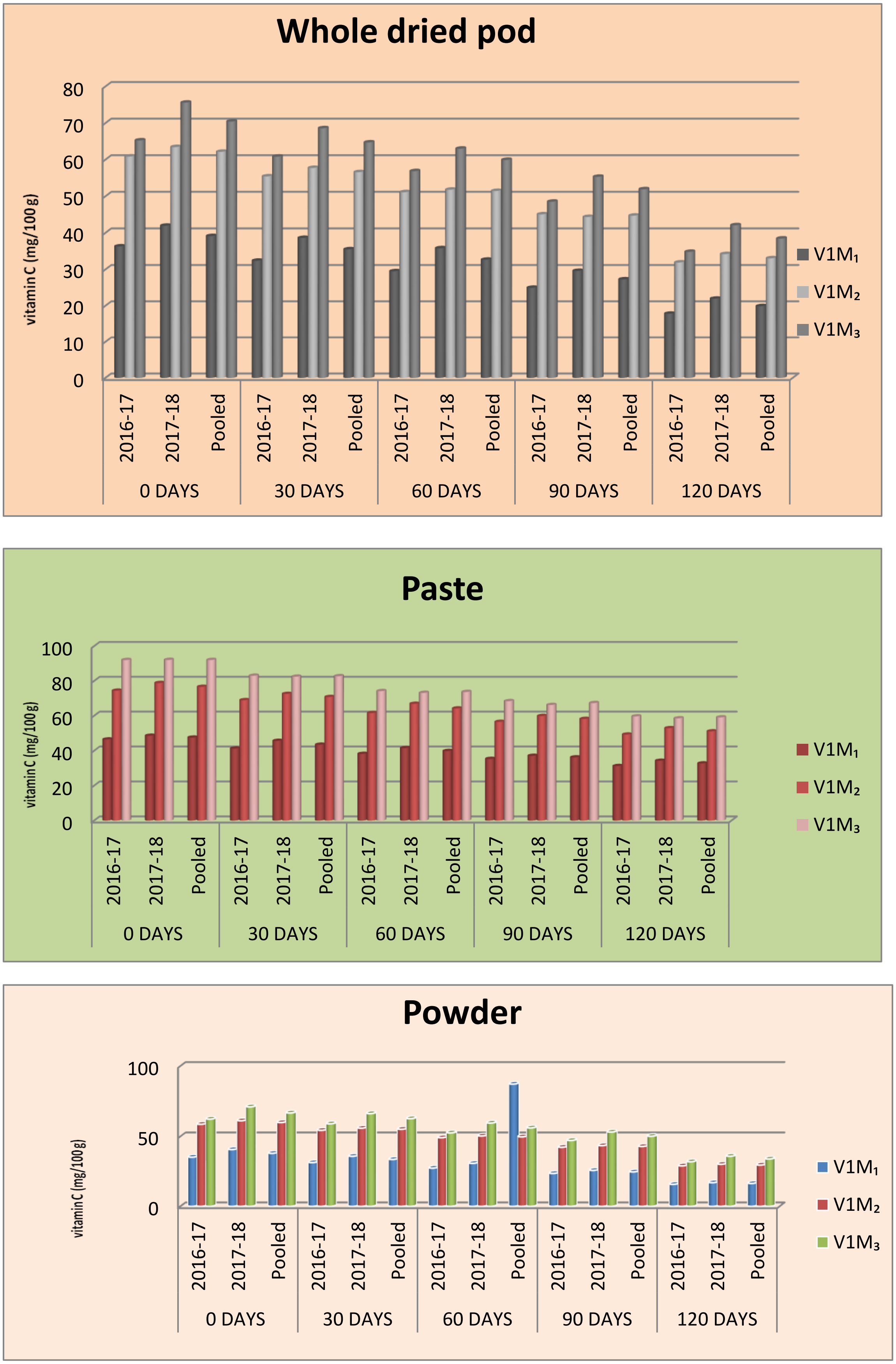


Figure 4.4: Influence of maturity stages and value added products on vitamin C (mg/100g) content of Naga king chilli

4.2.4. Capsaicin (µg/g)

Whole dried pod (V_1)

The influence of maturity stages on capsaicin content of powder is presented in Table 4.11. The data from the table reveals that the maturity stages had significant influence on capsaicin content on all dates of observation during both the years of observation as well as in the pooled data where the highest capsaicin content (22,072.11, 22,036.67 & 22,054.39) was recorded from red stage (M_3) followed by (19305.63, 17,142.33 & 18,223.98) from turning stage (M_2) and lowest (10,633.24, 9,364 & 9,998.62) from matured green stage (M_1) respectively on the last day of observation *i.e.*, 120th day.

Paste (V_2)

The influence of maturity stages on capsaicin content of powder is presented in Table 4.11. The data from the table reveals that the maturity stages had significant influence on capsaicin content on all dates of observation during both the years of observation as well as in the pooled data where the highest capsaicin content (6,856.91, 10,417.33 & 8,637.12) was recorded from red stage (M_3) followed by (4,956.64, 8,791.33 & 6,873.98) from turning stage (M_2) and lowest (3,177.20, 4,940.0 & 4,058.33) from matured green stage (M_1) respectively on the last day of observation *i.e.*, 120th day.

Powder (V_3)

The influence of maturity stages on capsaicin content of powder is presented in Table 4.11. The data from the table reveals that the maturity stages had significant influence on capsaicin content on all dates of observation during both the years of observation as well as in the pooled data where the highest capsaicin content (16,973.44, 17,159.67 & 17,066.55) was recorded from red stage (M_3) followed by (9,740.11, 14,299.33 & 12,019.72) from turning stage (M_2) and lowest (8,276.39, 7,895.67 & 8,086.03) from matured green stage (M_1) respectively on the last day of observation i.e., 120th day.

The data from the Table shows that the capsaicin content was found to be highest in red stage in all the three different value added products. This may be due to the difference in the initial content itself where red stage had the highest followed by turning stage and lowest in matured green stage, as reported by Ahmed *et al*., 1996; Sheela, l998; Mini and Wahab, 2002 and Robi and Sreelathakumary, 2004 that the capsaicinoids content increases with fruit maturation in relation to increased dry matter content in the order of green fruit<turning fruit<ripe fruit<sundried fruit. It was also found that the capsaicin content decreased with prolong storage time in all the three different products. Similar result was found by Giuffrida *et al*., (2014) who studied the pungency of red chili pepper powder during one year of storage at room temperature (20-24. °C) and at low temperature (- 18. °C) and concluded that during storage at room temperature, capsaicinoid amount was found to decrease progressively following a linear kinetics and after 12 months total capsaicinoids decreased to 75% of the initial value. Capsaicinoids may vary with the method of processing (Zewdie and Bosland, 2001). The present study also found that the capsaicin content was highest in whole dried pod followed by powder and lowest in paste. This is in good agreement with the finding of Bhagawati (2009) who observed a decrease in capsaicinoid content in all the products prepared from *Bhut* Red and *Bhut* Chocolate when compared with that of fresh chillies and recorded the highest capsaicin content in whole dried pods followed by powder and lowest in paste. The lower capsaicin content in paste may due to the peroxidase enzyme by catalytic activity. The similar result was reported by Schweiggert *et al*., (2006),

Topuz *et al*. (2011) and Toontom *et al*., 2012 as it is assumed that peroxidases catalyze capsaicinoid oxidation and plays a central role in its metabolism in pepper (Yu *et al*., 2005) and peroxidase activity is lower in fruits which have low moisture content (Bernal and Barcelo, 1996).

Table 4.11: Influence of maturity stages on capsaicin content (μg/g)of different processed products prepared from Naga king chilli.

Treatments	Days- 120		
	2016-17	**2017-18**	**Pooled**
Whole dried pod			
V_1M_1	10,633.24	9,364.00	9,998.62
V_1M_2	19,305.63	17,142.33	18,223.98
V_1M_3	22,072.11	22,036.67	22,054.39
SEm±	434.32	133.79	335.25
CD at 5%	**1502.96**	**462.98**	**1160.13**
Paste			
V_2M_1	3,177.20	4,940.00	4,058.33
V_2M_2	4,956.64	8,791.33	6,873.98
V_2M_3	6,856.91	10,417.33	8,637.12
SEm±	298.38	86.17	434.11
CD at 5%	**1032.54**	**298.17**	**1502.23**
Powder			
V_3M_1	8,276.39	7,895.67	8,086.03
V_3M_2	9,740.11	14,299.33	12,019.72
V_2M_3	16,973.44	17,159.67	17,066.55
SEm±	211.60	241.36	108.30
CD at 5%	**732.25**	**835.21**	**374.75**

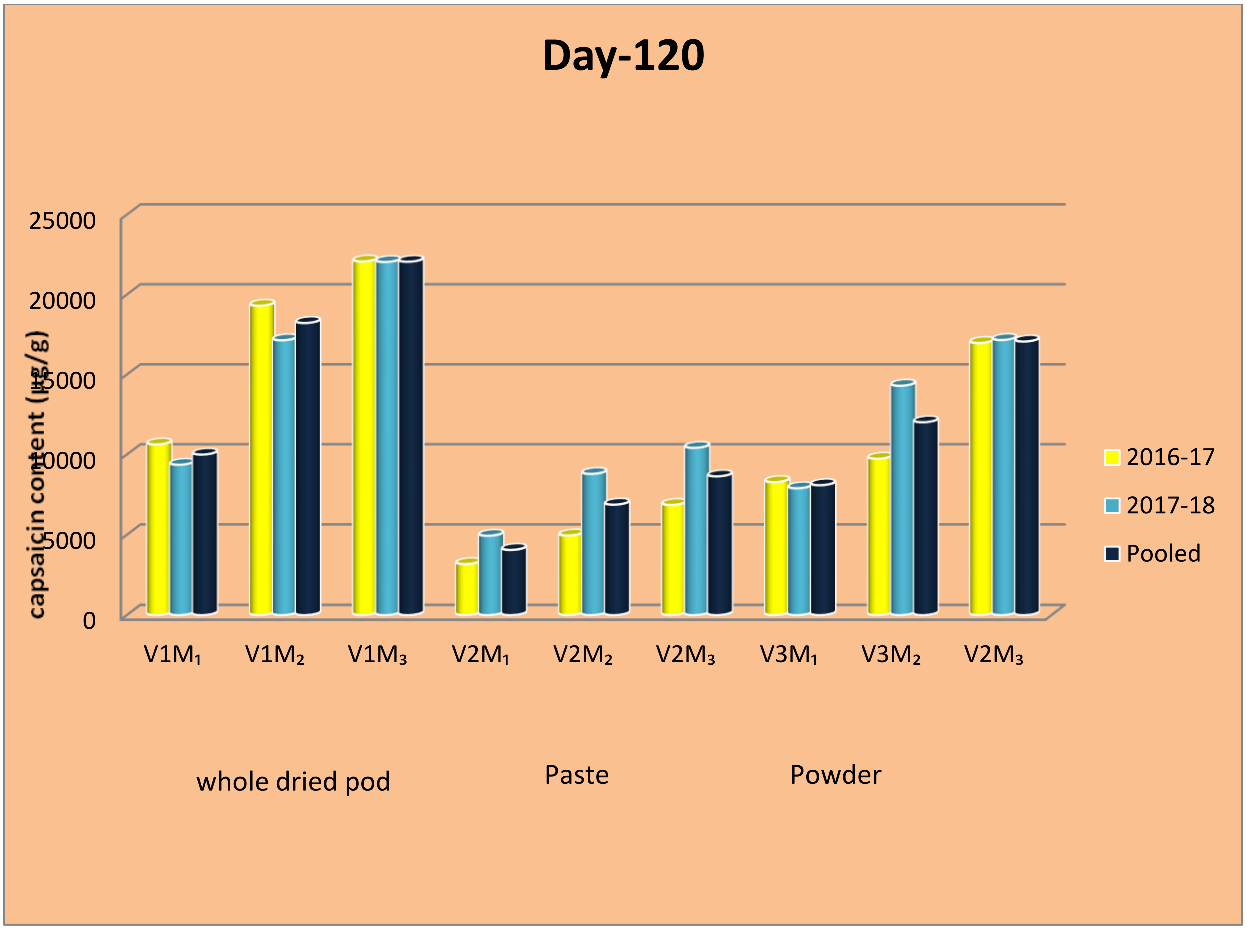


Figure 4.5: Influence of maturity stages and value added products on Capsaicin Content (µg/g) of Naga king chilli

4.3. Influence of blanching and different drying methods on colour retention of Naga king chilli.

4.3.1. Influence of blanching on colour retention

The effect of blanching on colour retention of dried Naga king chilli is depicted in Table 4.12. The data from the table reveals that blanching treatment had significant influence on the colour retention on all dates of observation and during both the years of observation i.e., 2016-17 and 2017-18 as well as in the pooled data analysis of the two years average data. The colour value gradually decreased with the storage time irrespective of the treatments. However, in both the years of observation as well as in the pooled data, it was also found that the blanched samples (B_1) showed higher colour value (192.33, 201.75 & 197.03) than the unblanched samples *i.e.*, B_0 (170.58, 180.76 & 175.67) on the first date (0 day) of observation which were reduced to (146.74, 147.34&147.03) in blanched samples and (125.21, 130.19 & 127.70) in unblanched samples respectively on the last date of observation (180^{th} day). Blanching is a pretreatment carried out primarily to inactivate natural enzymes (Cano *et al*., 1990) and loosens tissues which results in a faster drying process. Blanching is carried out to inactivate natural enzymes in order to improve color and texture of the product and it has been found to enhance the drying rate of chillies due to cell wall destruction (Turhan *et al*., 1997). In the present study, blanching of the fruit samples was done at around 90^{o}C for 3 minutes in hot water (Gupta *et al*., 2002) before drying and it was found that the blanched samples recorded a higher colour value than the unblanched samples. This may be due to the fact that blanching reduces the enzymatic browning and prevents the loss of colour (Chung *et al*., 1992). This finding is also in agreement with the reports of Turhan *et al*., (1997), Shivhare *et*

Plate 7(a): Drying of Sample for colour estimation

Plate 7(b): Samples of different treatment for colour estimation

al., (2000), Hossain *et al*.,(2007) and Anoraga *et al*., (2018) who found faster drying and higher colour value for the blanched sample rather than unblanched sample.

4.3.2. Influence of different drying methods on colour retention

The effect of different drying methods on colour retention of dried naga king chilli is depicted in Table 4.12. The data from the table reveals that different drying methods *viz*., sundrying, 50^{o}C, 60^{o}C and 70^{o}C had significant influence on the colour retention of the fruits on all dates of observation (up to 180 days) during both 2016-17 and 2017-18 as well as in the pooled data analysis. It was also found that all the oven dried samples (T_1= 50^{o}C, T_2= 60^{o}C & T_3=70^{o}C with highest being recorded from T_2) showed higher colour value than the sundried samples (T_0) on all dates of observation throughout the experiment. However, the colour value gradually decreased with the storage time irrespective of the treatments. The present finding of decreased in colour value with storage time as compared to initial value (Tepic and Vujicic, 2004) may be because many factors such as cultivar, temperature of drying, oxygen/air atmosphere, temperature, and moisture content during storage affect the retention of colour (Walker, 2011). Non-enzymatic browning is another cause of paprika colour degradation. It has been found that the water activity and temperature had a significant effect on the non-enzymatic browning rate of dried red peppers during their storage (Lee *et al*., 1991). In both the years of observation as well as in the pooled data, the highest colour value (250.70, 262.33 & 256.51) was recorded from samples dried at 60^{o}C (T_2) and the lowest (61.45, 67.36 & 64.28) from sundried samples (T_0) on the first date of observation (0 day) which were reduced to (189.99, 191.60 & 190.79) in T_2 and (44.11, 46.75 & 45.43) in T_0 respectively on the last date of observation (180th day).

The present finding where the traditional sundried samples recorded the lowest colour value as compared to all the oven dried samples may be due to prolonged exposure to heat, light, and oxygen (De-Guevara *et al*., 2002) because sundrying is a slow process that is weather dependent and is thus difficult to control and exposes the product to environmental hazard and results in products of low quality. Long dehydration times lead to poor quality products due to factors which include caramelisation, Millard reactions, enzymatic reactions and pigment degradation (Horner, 1993). Oberoi *et al*., 2005 also reported that the colour retention was significantly better in the chillies dried using batch-type dryer (BTD) as compared to conventional sun-drying (CSD). Hot air drying (HD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. It has been identified by a number of authors as a more efficient drying method. This is due to the fact that heat and mass transfer can be controlled during the drying process to achieve desired product quality (Adedeji *et al*., 2008).

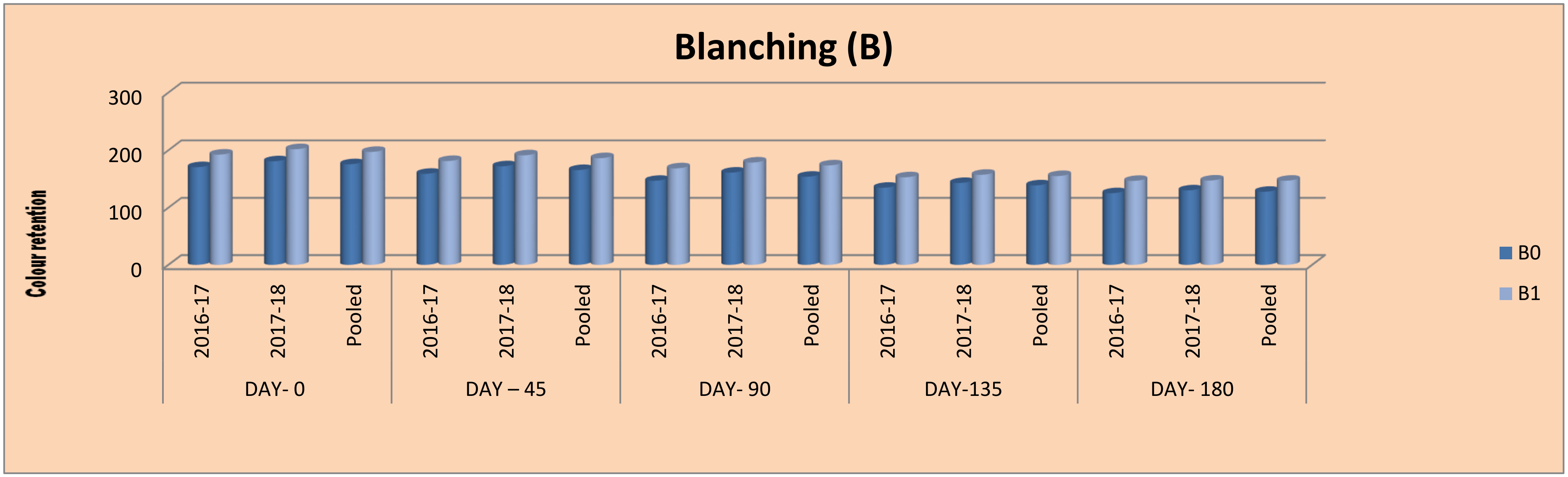
The present study was conducted with drying temperatures of 50^{o}C, 60^{o}C and 70^{o}C as reported by Berke and Shieh, 2001 that the temperature ranges from 45 to 70^{o}C (approximately 10% of moisture content), reduces drying time to less than 20 hrs which gives maximum colour values and minimizes the loss of volatile oils and discolouration. The data from the table reveals that the drying temperature of 50^{o}C and 60^{o}C (highest) resulted in better colour retention which may be due to depletion of some food nutrients as well as undesirable color and textural changes occurred during hot air drying (Adedeji *et al*., 2008) at 70C^{o}. Zapata *et al*., 1992 also reported that as a general rule the temperature should not exceed 50-60°C with less than 50 hrs drying period. Low drying rate gave superior color quality, (Minguez-Mosquera *et al*., 1994; Ibrahim *et al*, 1997). The product quality in respect of pigment retention and non-enzymatic browning indicated that the blanched red chillies should be dried at 55°C (Gupta *et al*., 2002). Vega-Galvez *et al*., 2009 also reported that the colour of the dried samples reduced with increase in drying temperature in which the highest air-drying temperature (90°C) presented the lowest value of colour while the maximum was at air-drying temperature of 70°C.

Interaction

The interaction between blanching and different drying methods was significant on all dates of observation during both the experimental years (2016-17 & 2017-8) as well as in the pooled data. The highest colour value was recorded from B_1T_2 (205.16) and lowest from B_0T_0 (40.39).`

Table 4.12: Influence of blanching and different drying methods on colour retention (ASTA colour unit) of Naga king chilli

Treatments	Days After Storage														
	DAY- 0			**DAY – 45**			**DAY- 90**			**DAY-135**			**DAY- 180**		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Blanching (B)															
B_0	170.58	180.76	175.67	159.07	172.07	165.56	146.87	161.10	153.98	134.74	143.11	138.93	125.21	130.19	127.70
B_1	192.33	201.75	197.03	181.24	191.13	186.18	168.56	178.64	173.61	152.98	157.31	155.14	146.74	147.34	147.03
SEm±	**0.36**	**0.65**	**0.48**	**2.71**	**0.15**	**1.32**	**0.29**	**0.29**	**0.26**	**0.24**	**0.38**	**0.12**	**0.14**	**0.13**	**0.11**
CD at 5%	**1.26**	**2.24**	**1.66**	**9.37**	**0.52**	**4.58**	**1.00**	**1.00**	**0.91**	**0.84**	**1.31**	**0.42**	**0.49**	**0.43**	**0.38**
Temperatures (T)															
T_0	61.45	67.36	64.28	56.96	63.47	60.21	51.8	58.46	55.13	47.35	50.98	49.16	44.11	46.75	45.43
T_1	221.38	225.60	223.49	207.91	216.99	212.45	193.82	204.1	198.96	177.55	180.51	179.02	167.27	168.37	167.82
T_2	250.70	262.33	256.51	236.21	246.09	241.15	219.39	231.06	225.22	200.01	207.62	203.82	189.99	191.6	190.79
T_3	191.38	209.71	200.55	179.51	199.83	189.67	165.88	185.86	175.87	150.53	161.71	156.12	142.51	148.34	145.42
SEm±	**0.96**	**1.80**	**0.93**	**0.93**	**1.19**	**0.77**	**0.52**	**0.63**	**0.44**	**0.90**	**0.78**	**0.42**	**0.64**	**0.46**	**0.30**
CD at 5%	**2.96**	**5.55**	**2.87**	**2.85**	**3.67**	**2.37**	**1.59**	**1.96**	**1.36**	**2.78**	**2.40**	**1.29**	**1.97**	**1.43**	**0.93**
Interaction (B×T)															
B_0T_0	54.69	60.68	57.68	51.08	57.68	54.38	47.84	53.84	50.84	42.35	46.63	44.49	38.70	42.09	40.39
B_0T_1	205.65	211.27	208.46	194.34	202.15	198.24	183.11	189.88	186.49	167.93	169.78	168.85	152.03	156.37	154.20
B_0T_2	234.85	248.87	241.86	218.73	234.36	226.54	202.25	216.48	209.36	185.77	195.68	190.72	173.67	179.18	176.42
B_0T_3	187.12	202.22	194.67	172.12	194.08	183.10	154.28	184.20	169.24	142.93	160.37	151.65	136.45	143.14	139.79
B_1T_0	68.22	74.05	71.13	62.85	69.27	66.06	55.76	63.09	59.42	52.36	55.34	53.85	49.53	51.42	50.47
B_1T_1	237.14	239.94	238.54	221.48	231.85	226.66	204.55	218.30	211.42	187.16	191.24	189.20	182.53	180.38	181.45
B_1T_2	268.30	275.79	272.04	253.71	257.83	255.77	236.53	245.66	241.09	214.26	219.58	216.92	206.31	204.02	205.16
B_1T_3	195.65	217.22	206.43	186.92	205.59	196.25	177.49	187.53	182.51	158.14	163.07	160.60	148.58	153.54	151.06
SEm±	**1.09**	**2.00**	**0.96**	**1.04**	**1.24**	**0.84**	**0.62**	**0.74**	**0.46**	**0.87**	**1.21**	**0.64**	**0.74**	**0.74**	**0.48**
CD at 5%	**3.17**	**5.84**	**2.79**	**3.02**	**3.62**	**2.46**	**1.82**	**2.15**	**1.34**	**2.53**	**3.52**	**1.86**	**2.15**	**2.16**	**1.41**



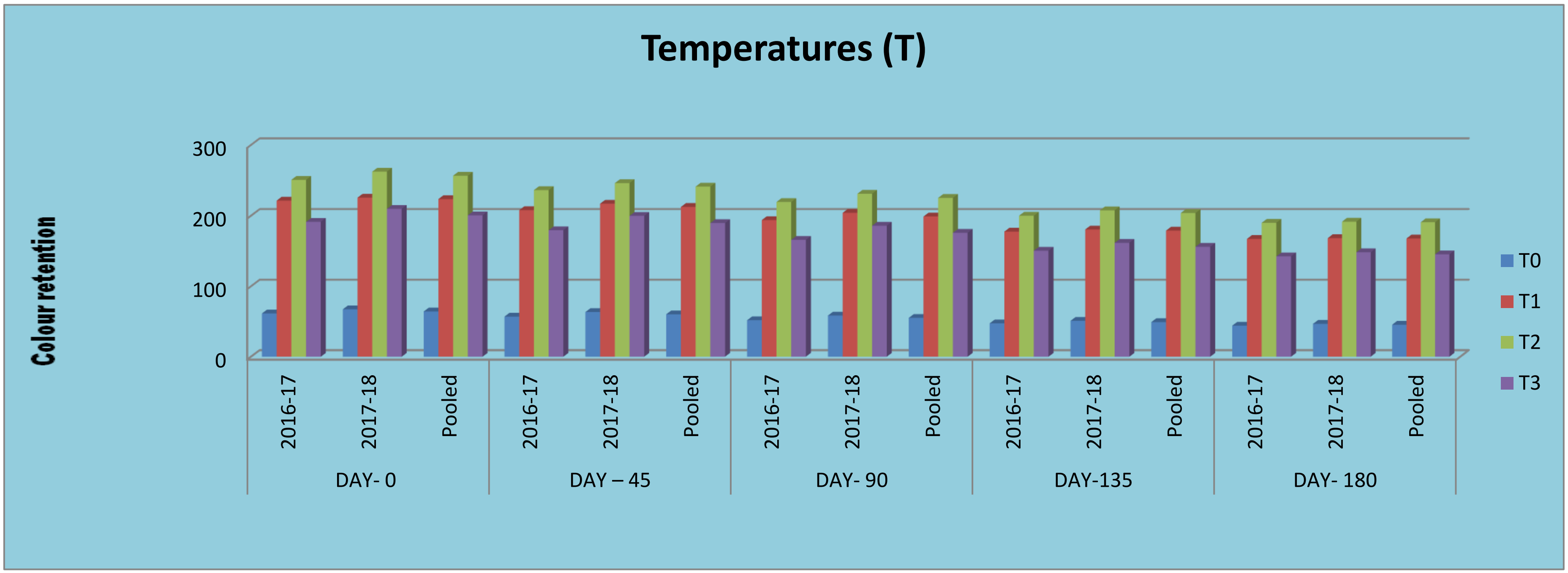


Figure 4.6. Influence of blanching and different drying methods on colour retention of Naga king chilli.

CHAPTER- 5

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The salient findings thus obtained from the present study are summarized below:

5.1. Influence of maturity stages and packaging materials on quality and shelf life of Naga king chilli

1. There was a general decreasing trend in the moisture content of all the maturity stages and in all the packaging treatments. Among the different maturity stages, the highest was recorded from matured green stage while lowest from red stage. Among the packaging materials, the highest was recorded from banana leaf while lowest from newspaper on the last day of observation. Both the maturity stages and packaging materials had significant influence on the moisture content while the interaction between the maturity stages and packaging materials was not significant on all dates of observation.

2. The rotting % increased with the storage time in all the maturity stages and in all the packaging materials. Among the different maturity stages, the highest was recorded from red stage while the lowest from matured green stage. Among the packaging materials, the highest was recorded from perforated polythene while the lowest from newspaper on the last day of observation. The influence of maturity stages and packaging materials as well as their interaction on rotting % was not significant on most of the dates of observation.

3. The sensory score decreased with storage time in all the maturity stages and in all the packaging materials. Among the different maturity stages, the highest was recorded from turning stage while lowest from red stage. Among the packaging materials, the highest was recorded from banana leaf while lowest from control on the last day of observation. The maturity stages and packaging materials had significant influence on the sensory evaluation while their interaction did not significantly influence on all dates of observation.

4. Among the different maturity stages, the highest shelf life was recorded from matured green stage while lowest from red stage. Among the packaging materials, the highest shelf life was recorded from newspaper packaging while lowest from control. The maturity stages and packaging materials had significant influence on the shelf life while their interaction did not significantly influence on all dates of observation.

5. The TSS content increased till the last day in matured green stage, 6th day in turning and 4th day in red stage. The highest was recorded from matured green stage while lowest from red stage. While in all the packaging treatments, it increased till 6th day and then decreased in the later days. The highest was recorded from newspaper and lowest from perforated polythene on the last day of observation. The maturity stages and packaging materials had significant influence on the TSS content while their interaction did not significantly affect the TSS content on all dates of observation.

6. The vitamin C content increased till the last day in matured green stage and 6th day in turning while in red stage, it decreased with the storage time. The highest was recorded from turning stage while lowest from red stage. The influence of maturity stages on vitamin C content was significant. While for the packaging treatments, the vitamin C content increased till the last day in perforated polythene and banana leaf while in control and newspaper it decreased in the later days of storage. The highest was recorded from banana leaf while lowest from control on the last day of observation. The influence of packaging materials on vitamin C content was significant on most of the dates of observation while their interaction was not significant.

7. The capsaicin content decreased in red stage while it was little higher than the initial content in matured green and turning stage on the last day of observation. The highest was recorded from red stage and lowest from matured green stage. While in all the packaging treatments, the capsaicin content decreased with storage time. The highest was recorded from newspaper and lowest from perforated polythene on the last day of observation. The maturity

stages and packaging materials had significant influence on the capsaicin content.

5.2. Influence of different maturity stages on quality and shelf life of different processed products (whole dried pod, paste and powder)

1. The maturity stages had significant influence on the sensory evaluation of whole dried pod, paste and powder. The sensory score gradually decreased in all the products with storage time. However, for all the three products, the highest was recorded from red stage and lowest from matured green stage on the last day of observation.

2. The maturity stages had significant influence on the shelf life of whole dried pod, paste and powder. For whole dried pod, the highest was recorded from turning stage and lowest from red stage. For paste and powder, the highest was recorded from red stage and lowest from matured green stage.

3. The maturity stages had significant influence on vitamin C content of whole dried pod, paste and powder. It decreased in all the products with storage time. However, for all the three products, the highest was recorded from red stage and lowest from matured green stage on the last day of observation.

4. The maturity stages had significant influence on capsaicin content of whole dried pod, paste and powder. For all the three products, the highest was recorded from red stage and lowest from matured green stage on the last day of observation.

5.3. Influence of blanching and different drying methods on colour retention of Naga king chilli.

1. The blanching treatment had significant influence on the colour retention. The colour value gradually decreased with the storage time. The colour retention was highest in blanched samples and lowest in unblanched samples on all dates of observation.

2. The different drying methods (sun drying, 50^{o}C, 60^{o}C and 70^{o}C) had significant influence on the colour retention of dried Naga king chilli fruits. The colour value gradually decreased with the storage time. The highest was recorded from samples dried at 60^{o}C and lowest in sundried samples on all dates of observation.

From the results of the present experiment, it can thus, be concluded that:

1. Among the different maturity stages, matured green stage (M_1) gave the best result in terms of moisture content, rotting %, shelf life and TSS. While among the packaging materials, newspaper packaging (P_1) gave the best result in terms of rotting %, shelf life, TSS and capsaicin content.

2. Among the different maturity stages for value added products, the red stage (M_3) is overall considered the best: for whole dried pod (in terms of sensory evaluation, vitamin C and capsaicin content); for paste (in terms of sensory evaluation, shelf life, vitamin C and capsaicin content) as well as for powder (in terms of sensory evaluation, shelf life, vitamin C and capsaicin content).

3. For better colour retention of dried naga king chilli fruits, blanching (B_1) and drying at a temperature of 60^{o}C (T_2) is considered the best.

Future line of work

1. To work on different perforation percentage and densities of polythene packaging.

2. To work on different packaging containers for the storage of value added products to find the suitable container that could retain the quality parameters of Naga king chilli products.

3. To work on different level of final moisture content (%) of the dried chilli to study on colour retention.

4. To work on anti oxidants properties of Naga king chilli.

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