EFFECT OF LOW TEMPERATURE AND ICE TREATMENTS ON THE POST-HARVEST QUALITY OF SELECTED CULTIVARS OF CAULIFLOWER, CABBAGE AND KOHLRABI: AN ANALYSIS OF ANTIOXIDANT ACTIVITY, TOTAL PHENOL AND L- ASCORBIC ACID

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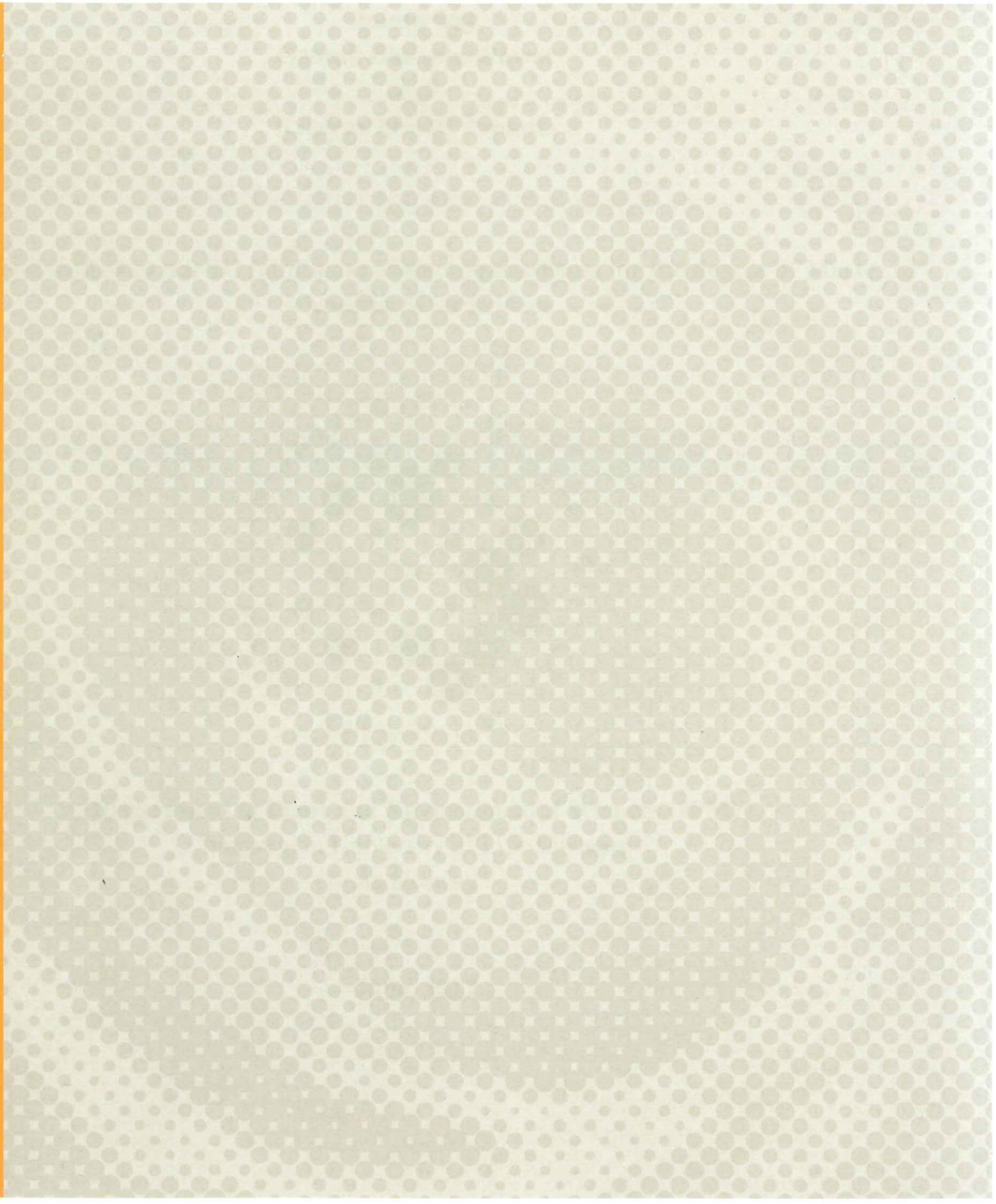

Effects of low temperature and ice on post-harvest storage quality of selected cultivars of cauliflower (*Brassica oleracea* sps. *botrytis*), cabbage (*Brassica oleracea sps. capitata*) and kohlrabi (*Brassica oleracea* sps. *gongyloides*): An analysis of antioxidant activity, total phenol and L-ascorbic acid

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CREDIT

The Department of Plant and Environmental Sciences, IPM, is the largest department and international gateway for the UMB's (Norwegian University of Life Sciences) multifacet study programmes: Agroecology, Radioecology, Plant Science, Plant Pathology and Sustainable Water and sanitation associating research institutions in Oslo and Akershus University College of Applied Sciences. Established in 1986, IPM's contribution to international development lies in the interface between research, education (Bachelor, Master and PhD programmes) and assignments.

The IPM Master thesis is the final thesis submitted by students in order to fulfill the requirements under the IPM Master programme "Master of Science in Plant Science".

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ABBREVIATIONS

%	Percent
˚C	Degree Celsius
AA	Antioxidant activity
CA	Controlled atmosphere
cv.	Cultivars
DHA	Dehydro-ascorbic acid
DM	Dry matter
DNA	De-oxy ribonucleic acid
L-AA/L-asc	L-ascorbic acid
LSD	Least Significant Difference
FCR	Folin Ciocalteu's Phenol Reagent
FRAP	Ferric Reducing Ability of Plasma
FW	Fresh Weight
GAE	Gallic Equivalents (Unit of LAA)
HPLC	High Performance Liquid Chromatography
RH	Relative humidity
RNS	Reactive nitrogen species
ROS	Reactive oxygen species
SKP	Senter for klimaregulert planteforskning
Sps.	Species

TP	Total Phenol
TSS	Total soluble solids
UMB	Norwegian University of Life Sciences
VPD	Vapour pressure deficit
WP	Wettable Powder

ABSTRACT

Brassica, the only vegetable crop attributed with the potential to protect cancer and cardiovascular diseases were investigated in present study. The antioxidant activity, total phenol and L-ascorbic acid in 3 selected cultivars of cauliflower, cabbage and kohlrabi grown in Ås Norway (59°40'N) were stored at 0 °C, 5 °C and ice for 6-7 weeks. Antioxidants were analyzed by FRAP Assay in Konelab, total phenols by Follin-Ciocalteu's phenol Reagent (FCR) in Konelab and L-ascorbic acid by HPLC. Overall, the low temperature enhanced the postharvest quality of selected vegetables. There was a variation in the content of antioxidant from 0.19-0.78 mmol/100g FW, 0.22-1.92 mmol/100g FW and 0.30-0.45 mmol/100g FW in cauliflower, cabbage and kohlrabi respectively where the exceptionally highest value was observed in ice stored red cabbage cv. Rovite (1.92 mmol/100g FW). The total phenol in the present study as a part of antioxidant was found to be varying from 39.14-85.39 mg GAE/100g FW, 29.12-166.89 mg GAE/100g FW and 26.81-42.27 mg GAE/100g FW in cauliflower, cabbage and kohlrabi respectively. Here, the dramatically high total phenol among the studied Brassica was noticed in Rovite stored in ice storage condition. Among treatments, the antioxidant activity and total phenolics increased at both 0 °C and 5 °C storage conditions in cauliflower while they did not significantly increase in cabbage and kohlrabi. Unlike 0 °C and 5 °C, the storage treatment in ice exhibited mixed effects with significant increase in the amount of antioxidant activity and total phenol in cauliflower cultivars (Flamenco and Celio) and cabbage cultivars (Castello and Rovite) or no significant increase in cauliflower cv. Nemo, cabbage cv. Bartolo or even decrease in kohlrabi cultivars. In the same way, L-ascorbic acid was ranging from 51.62-75.18 mg L-asc/100g FW, 32.77-46.27 mg L-asc/100g FW and 25.93-39.02 mg L-asc/100g FW respectively in cauliflower, cabbage and kohlrabi; with the highest value in cauliflower (Celio) at 0 °C. The analysis of L-ascorbic acid at different treatments in cauliflower cultivars illustrated that ice was the best storage condition though it decreased significantly in Celio. Meanwhile, L-ascorbic acid content decreased in cabbage and kohlrabi cultivars during storage except red cabbage (Rovite) where it increased significantly. Moreover, the variation in the content of dry matter in cauliflower, cabbage and kohlrabi ranged from 5.54-8.56%, 5.85-9.61% and 3.93-5.70% respectively; with a highest value in Bartolo cabbage at harvest and depicted a declining trend over storage among all the crops under study. The two-way Anova analysis and Turkey's LSD for the treatment means revealed that the low temperature treatment of 0 °C was the best storage condition for the selected Brassica vegetables as it reduces the ongoing metabolism to the minimum. The present study thus suggests that this low temperature treatment preferably 0 °C can be used to commercially store Brassica vegetables.

Key words: *Brassica*, vegetables, cauliflower, cabbage, kohlrabi, antioxidant activity, L-ascorbic acid, total phenol, dry matter, low temperature, ice, storage, post-harvest

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1 INTRODUCTION

Among vegetables, Brassica crops comprise the large group of about 350 genera and 3000 species from family *Crucifereae*. Its abundance comprises from the vegetable forms to the forage of the cole crops such as broccoli, Brussels sprouts, cauliflower, cabbage, kale, collards, kohlrabi, mustard, turnip and many more. The main vegetables are from *Brassica oleraceae* species covering cauliflower, cabbage and kohlrabi; the important and commonly grown vegetables crops worldwide for their own significance due to their high nutritive properties and wider adaptability.

Brassica crops, the group of vegetables regarded for potential cancer protection (Chun et al. 2004), are important because of their high nutritive and dietic values. The edible parts of those crops are rich in chemical composition. Wide range of vitamins, minerals, fiber and carbohydrate can be obtained from the Cole crops which also contain high amounts of vitamin C, soluble fiber and multiple potential anti-cancer nutrients. Among them, the most important from dietary point of view is the antioxidant property. The phytochemicals such as vitamin C, flavonoids, carotenoids and other phenolics are the constituents that contribute this property. Red cabbage is important due to its exceptionally high content of antioxidant property i.e. three times higher than the ordinary cabbage. Researches show that these cole crops are rich in cyanidin, indole-3-carbinol, chemical compound which boosts DNA repair in cells and appears to block the growth of the cancer cells. Those substances in the crop have the beneficial properties for our health including the phenolic compounds, ascorbic acid, β-carotene and α- and β-tocopherols and glucosinolates as well (Singh et al. 2007).

Natural antioxidants are believed to possess a wide range of biological effects, including anti-bacterial, anti-viral, anti-inflammatory, anti-allergic, anti-thrombotic and vasodilatory activity (Cook & Samman 1996). Overall, fruits and vegetables contain an important property which may attribute against carcinogenicity, mutagenicity and ageing activity (Liyana Pathirana & Shahidi 2006). Several epidemiological findings have reported a negative correlation between the consumption of fruits and vegetables and the reduced risk of carcinogenic diseases (Wattenberg et al. 1989), with due credit to glucosinolates (Verhoeven et al. 1997). The antioxidants,

carotenes, tocopherols and ascorbate have a great potential to prevent and treat malignant diseases (Kurilich et al. 1999). Similarly, epidemiological studies have highly correlated the intake of these compounds and vitamins from fruits and vegetables with a reduced risk of several types of cancer (Ramos et al. 2011). In the context that non-communicable chronic diseases are substantial contributors to the global burden of disease, death and disability; minimizing these effects has been essential. In agreement to this, WHO in 2002 reported the deaths of 59% of the 57 million annually accounting 47% of the global disease burden through chronic diseases which compels mankind to minimize this and stay healthy and safe (Guilbert 2003). On the other hand, heart disease and cancer cause almost two-third of the overall share of the disease in European region (Robertson 2004). With the increasing concern of human for healthy diet and nutrition, antioxidant property has been the major area of research (Demo et al. 1998).

Researches show that the post-harvest loss in terms of both quality and quantity is alarming in fruits and vegetables as they are more delicate and succulent products which can easily be degraded in terms of physical and nutritional quality either visible or non-visible. The main reason behind this is the ongoing respiration within the living tissues after harvest leading to perishability. Perishability may be governed by different conditions. The crops under study; cauliflower, cabbage and kohlrabi are more susceptible to the high temperature and other factors. Moreover, a lot of changes in the nutritional properties and quality are associated with the storage. Overall, Plich (1997) stated that lowering the storage temperature is the potential key to enhance the post-harvest life of fruits and vegetables.

The aim of this study is to investigate the effect of different storage conditions on the post-harvest quality in selected cultivars of cauliflower, cabbage and kohlrabi. For this, 3 cultivars of Cauliflower namely ‘Nemo’, ‘Flamenco’ & ‘Celio (hybrid ‘Romanesco), 3 cultivars of cabbage ‘Bartolo’, ‘Castelo’ & ‘Rovite’ and 3 cultivars of kohlrabi, ‘Kordinal’ ‘Korridor’ and ‘Kolibri’ were used. Among three cultivars of Cauliflower, Romanesco is hybrid cauliflower cultivar preferably of growing concern either due to its unique shape and high nutritional value while Rovite, the red cabbage because of its exceptionally high amounts of antioxidant activity and total phenolic content. They were analyzed for different attributes of post-harvest quality viz; antioxidant capacity, total phenolics (TP), Vitamin-C i.e. L-ascorbic acid and dry matter (DM).

1.1 Objectives of the study

I. To observe and know the effects of low temperature and ice treatments in post-harvest quality of selected cultivars of some common Brassica crops

II. To analyze different quality attributes such as antioxidant activity, total phenol, L-ascorbic acid and dry matter

III. To explore the optimum temperature and storage condition for the selected Brassica crops

2 LITERATURE REVIEW

2.1 Botany

The large group of cole crops from *Crucifereae* (also known as *Brassicaceae*) comprises of about 350 genera and 3000 species. The family comprises cool season vegetables such as broccoli, Brussels sprout, cauliflower, cabbage, collards, kale, kohlrabi, mustard, turnip, water cress etc. Among them, cauliflower, broccoli, cabbage, and kohlrabi are important and commonly grown vegetables though all of them have their own significance and special use. Plants are usually herbaceous annuals, biennials, or perennials (Soengas et al. 2011). Leaves may be thick and succulent, with or without a waxy bloom. Some species grow as high as two meters on a shallow and fibrous root system. The inflorescence is a terminal raceme of showy yellow or white flowers. *Crucifereae* got its name as the flowers bearing four perpendicular petals (aestivation) resembled a crucifix to the medieval Europeans (Maggioni et al. 2010). The genus Brassica is the most important group of family *Brassicaceae* containing 37 different species of the economically important plant foods with health benefits (Soengas et al. 2011). The main vegetable species of the genus is *Brassica oleraceae* which comprises both vegetable and forage forms. The genus is classified into oilseed, forage, condiments and vegetable crops depending on the relative use and significance of the crop by using their buds, inflorescences, leaves, roots, seeds and stems. The same species may be utilized into different forms or types.

Flowers also have four sepals, a two-celled, superior ovary with a single stigma and style and six stamens, two of which have shorter filaments than the others in tetradynamous condition. The bi- or tetralocular carpel is superior divided by a false septum. The anthers at the bud stage are at lower level than the stigmas out of which four of them elongate to carry out the anthers as high as or above the stigma level before flowering (Quijada et al. 2007). The fruit (seed pod) is a siliqua with a persistent, beaked style. At maturity, siliques dehisce longitudinally to release the small round brown or black seeds. The surface of the siliqua and the seed is smooth. Seeds mature fifty to ninety days after fertilization. The species is insect cross-pollinated with self-pollination prevented by a sporophytic self-incompatibility system. The naturally occurring *Brassica oleracea* are always diploid containing nine pairs of chromosomes (Xiao-Dan et al. 2009).

The rigorous artificial selection and many years of evolution led to A and C genome in *B. napus* thus gaining a distinction from A genome in *B. rapa* and *B. juncea*, the C genome in *B. oleracea* and *B. carinata* (Figure 1). The chromosome numbers in the haploid genomes are specified in the parenthesis.

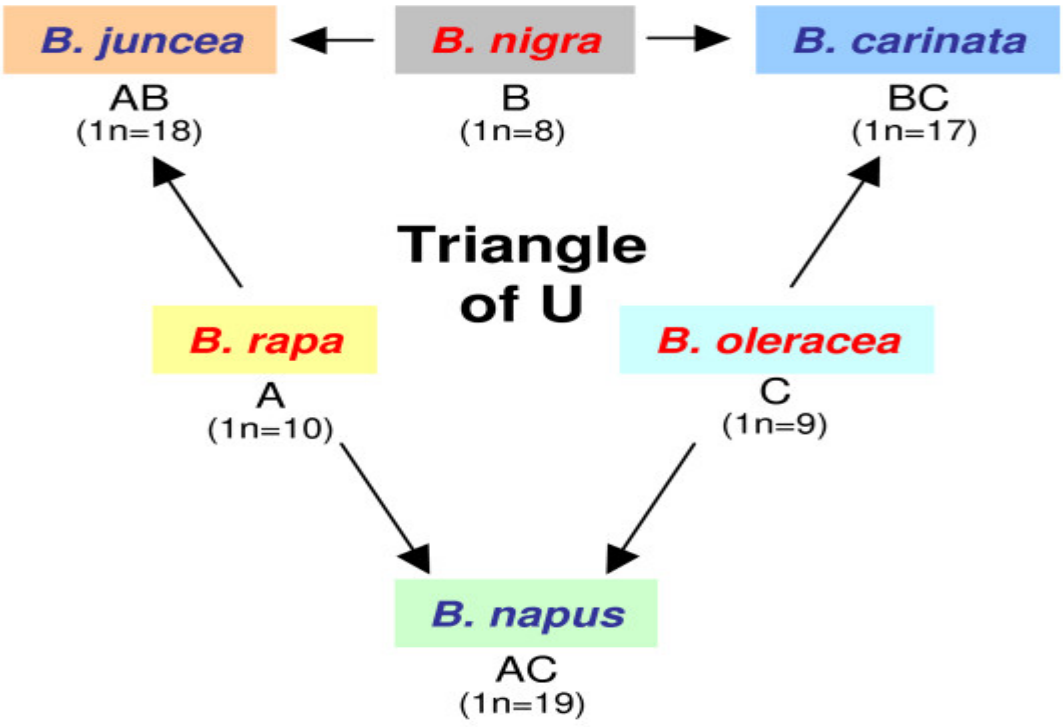

Figure 1. Brassicas and their genetic relationship by the triangle of U (U 1935)

These crops by the name cole crops are considered to be somewhat cold and frost tolerant with optimum growing temperatures of about 15 °C, but plants will grow slowly even at -10 °C (Klein & Perry 1982). Young plants are more tolerant than older plants. Crops whose vegetative parts are eaten are generally more tolerant of low temperatures than crops whose reproductive parts are consumed. The market requirements in all vegetables have their own unique characteristics in terms of maturity, size, color, taste, shape, and popularity of the cultivar.

2.2 Origin and domestication of Brassica

The archaeological proof regarding the origin and domestication of Brassica crops are lost over time. Thus, the literary and linguistic studies are to be referred to figure out the origin of these crops. The fact that ancient Greek and Latin literature has been using these crops in their early works whereas the ancient Egyptian did not report them anywhere which compels us to locate their origin as deep-rooted in native Europe around Greece. Some cole crop terminology indicating the morphological feature as the solid upright stem i.e. kaulos, caulis can be easily traced back from the ancient Greek and Latin civilizations. The linguistic, literary, and historical points of view are in a support that the domestication of *Brassica oleraceae* was in the ancient Greek-speaking area of Central and East Mediterranean (Maggioni et al. 2010). Turnip (sps *rapifera*) is believed to have been originated from Europe (Quijada et al. 2007). *Brassica rapa* was first domesticated in Europe as a biennial plant which later evolved to give rise to annuals through rigorous breeding and selection (Burkill 1930). The primary center of origin of oleiferous form of *Brassica rapa* is Europe while the eastern forms were evolved in northwest India and at the same time the Chinese forms as leafy vegetables in China (Quijada et al. 2007). The three ecotypes of oil yielding *B. rapa*: brown sarson, yellow sarson and toria are found in India (Singh 2003).

The hypothesis regarding the domestication of cole crops is that the primitive people- the wanderers - got their sight into the wild fleshy leaves of Brassica species. As they found them to be useable as food, they introduced them along with other already domesticated plants into their home gardens by the side or the proximity of their dwellings; ultimately giving rise to the domesticated leafy kale. They were later spread throughout the world in different names as galega cale in Portugal, curly kale in Northern Europe, black kale in Tuscany, rasthan in Montenegro among others (Prakash & Hinata 1980). But the doubt and dispute arises regarding the first use and introduction of cole crops when the wild progenies of cole have also been found on the Mediterranean coasts and the rocky coasts of Northwest Atlantic region on the other hand. Brassica seeds are found in prehistoric archaeological navigations as well. *Brassica oleracea* archaeology can be traced back before ancient Roman civilizations while *B. rapa* and *B. nigra* are

better preserved and found be studied from Neolithic and Bronze sites only (Maggioni et al. 2010).

2.3 Historical Development of Brassica

Brassica vegetables are referred to as the native of Europe. The wild progenies of *Brassica* are found on the rocky Atlantic coasts of Europe (Bay of Biscay) and Britain. The free living *B. oleraceae* populations found along the Mediterranean coast are merely stated as the feral and weedy escapes from cultivation. Researchers are now in an opinion that the free living *B. oleraceae* populations found along the Europe and the Mediterranean as cabbage and kale dispersed into Mesopotamia and Egypt. Trade routes lead them to spread further throughout the old world ultimately competing *B. rapa* of East Asian origin in China. When trade with the New World began, all of the cole crops were taken to the Americas. Broccoli and cauliflower diffused from the Mediterranean (cauliflower earlier than broccoli) to elsewhere in the Near East, northern Africa, and Europe. According to Maggioni et al. (2010), cauliflower was mentioned in Turkey and Egypt in the sixteenth century and in England and France in the seventeenth century. Both broccoli and cauliflower were first described in the United States in 1806, but production did not flourish until the 1920s. Interest in broccoli in central and northern Europe increased after the crop became popular in the United States and afterwards dispersed worldwide, broccoli production is increasing.

Brassica rapa has been found to have been grown naturally from the west Mediterranean region to central Asia and is still present as feral types throughout this area. The ancient reference pertains to yellow sarson in ancient Veda books and Sanskrit literary works such as the Upanisadas and the Brahmanas (c. 1500 BCE), where it was referred to black mustard (*Brassica nigra*) and yellow sarson (*Brassica rapa*) as ‘Sarshap’ and ‘Siddhartha’ respectively (Prakash & Hinata 1980). Europe, western Russia, Central Asia and the east has been considered as the secondary centres of origin with their widest distribution. The first domestication of this crop should have probably been possible due to this wide distribution. The selection from the available variation of the leafy vegetables made it possible for the huge diversity in Chinese cabbage (Quijada et al. 2007).

2.4 Diversity of Brassica

Brassica (cabbage family) consists of five groups:

a. *Brassica oleracea*
   sps botrytis (cauliflower)
   sps capitata (cabbage)
   sps gongylodes (kohlrabi)
   sps acephala (kale)
   sps italica (broccoli)
   sps gemnifera (Brussel sprouts)

b. *Brassica napus*
   sps rapifera (Swede)

c. *Brassica rapa* (syn. *B. campestris*)
   sps pekinensis (Chinese cabbage)
   sps rapifera (turnip)
   sps chinensis (pak-choi)

d. *Raphanus sativus*
   sps sativus (radish)
   sps niger (oriental radish)

e. *Eruca sativus* (Rucola salat)

2.5 Variation of Brassica

The extreme plasticity of the species has allowed differentiation under human selection because of the specialization of different plant organs giving rise to various crops and uses. For example, the leaf is eaten in case of cabbage and leafy kale while stem is consumed in kohlrabi and marrow stem in kale. Similarly, the inflorescences are the edible parts of broccoli and cauliflower while auxiliary bud of Brussels sprout is consumed. The tremendous variation in the form and color is also found in Brassicas depending upon the crop and variety (Maggioni et al. 2010).

2.5.1 Cauliflower *(Brassica oleracea L.var. botrytis)*

2.5.1.1 Botany and growing conditions

It is an important crop of *Brassicaceae* and is supposed to have originated from the Northeast Europe i.e. France and Italy and Mediterranean region (Maggioni et al. 2010). It is an annual plant that reproduces by seed. Cauliflower is the large, flat, central clusters of flower buds called curds. The inner leaves on some kinds curve inwards to cover and blanch the curd.

2.5.1.2 Soil and climate

This vegetable needs an abundant amount of water and rich, fertile soil. They need a long, cool growing season. Light frost won't hurt the seedlings. It is grown in neutral or slightly alkaline soil. If the soil is too acidic, the plants will be unable to obtain all the trace elements they need, and may develop whiptail as a result of Molybdenum deficiency. It is advised to use a friable soil with an addition of leaf mold or peat moss and sand. Under warm, humid climatic conditions, seedling growth and planting of green cauliflower should be timed when minimum temperatures fall below 21 °C (Csizinszky 1996).

2.5.1.3 Propagation

Seeds should be sown indoors in full sun and air circulating green house, 8 to 10 weeks before they are to be transplanted outdoors. Cauliflower is a very sensitive crop to stress. Therefore, small heads on dwarf plants may form on seedlings that are overly hardened, carelessly transplanted, planted too deep or stressed by weather. Hardening gives the low mortality of the seedlings after transplanting or high plant and seedling establishment rate. The plant to plant and row to row space is recommended to be 40 and 65 cm each respectively. Yields, averaged over the plant spacing and N and K rates, were highest in the January planting and successively lowest in the October planting (Csizinszky 1996). Any type of stress to the crop leads to the reduction in the head size called `buttoning`. As for all Brassicas, Cauliflowers are also recommended to grow with crop rotation to avoid many soil borne diseases and ‘Club root’.

2.5.1.4 Irrigation

After transplanting, light irrigation is recommended which will help to establish the seedlings firmly in the field. Particularly in case of summer season where there is scarcity of water, mulch around the plant can conserve the moisture for long time.

2.5.1.5 Harvesting

Cauliflowers grow up as clusters of flat, central and large floral buds known as curds. Depending upon the kinds of cauliflower, inner leaves cover the curds protecting them from being unattractive brownish-green colored. A cauliflower is supposed to be ready for harvesting when the upper surface of the curd is fully exposed, the flower buds are small, the head is smooth and the inner leaves no longer cover it. The curd is cut just below the head. Typically, only the head (the *white curd*) of aborted floral meristem is eaten, while the stalk and surrounding thick, green leaves are used in vegetable broth or discarded. The yield varies from 0.5-1.0 kg per head depending on many conditions on which it is grown such as variety, time, nutrient status of the soil, planting distance, insect-pest infestation, disease occurrence, harvesting time etc (Newenhouse 1997).

2.5.1.6 Varieties

Snow Crown; White Contessa; Alert.

Kathmandu local, Sarlahi Dipali, Dolpa Snowball are the prominent cultivars grown in Nepal whereas Nemo, Flamenco and Celio (pyramidial/ romanesco) are the one grown in Norway.

2.5.1.7 Pests and Diseases

The major pests associated with cauliflower are cabbage root fly affecting mostly the seedlings by rotting and wilt; cabbage gall weevil infesting stunted growth and misshapen roots and wire stem causing rotting stems on seedlings. The common diseases of cauliflower are club root affecting the bluish leaves, wilting and dying of the plant while powdery mildew causes light grey powdery patches in the leaves and the shoots eventually killing the plant.

Classification of Cauliflower

Cauliflower has the following four main groups depending on **the habitat and origin** of the type:

Italian: They have diverse looks, having biennial and annual growth habits. This group includes different colored cultivars for example white, various green, purple, yellow, Romanesque, etc. This group is considered to be the ancestral as others were derived from this group.

Northwest European biennial: These are grown in the Europe for the spring and winter seasons. This group includes the old cultivars Roscoff and Angers. Those cultivars were developed in France during 19^{th} century.

Northern European annuals: These cultivars are grown as summer and fall season in the Europe and North America. These cultivars were developed in Germany during 18^{th} century. Examples are old cultivars Erfurt and Snowball.

Asian: These are tropical cultivars grown in India and China was developed in India during the 19^{th} century, for example Early Patna and Early Benaras, Kathmandu local.

Cauliflowers are divided into two main groups depending upon **the time or season of growing**.

Summer Cauliflowers are the varieties, which are grown during summer season and are quickly growing in heavy fertile soil. Summer cauliflower are grown out-door during spring and harvested in summer and autumn.

Winter Cauliflowers are hardy and tolerant to the cold and soil conditions and can be grown in almost all type of soils. They are characterized as the slow growing types. The sowing to harvesting time for the cauliflower differs according to the season it is grown i.e. 18-24 weeks for the summer cauliflowers and that of 36-38 weeks for the winter cauliflower.

2.5.2 Cabbage (*Brassica oleraceae L. var. capitata*)

Cabbage is referred to the head. The head composes the tightly compacted overlapping leaves formed on a shortened stem. Heads are typically round, but may be large or small depending on the variety. Unlike most cabbages having smooth thick leaves, Savoy variety bears crinkled leaves.

Cabbage is multidimensional in use. It is thus eaten fresh as coleslaw, boiled and used to make stuffed cabbage leaves or eaten with corned beef a potatoes. The Norwegian traditional dish 'Forikol', a typical Norwegian dish, comprises cabbage cooked for 3-5 hours mixed with the lamb and served with potatoes and sauce. 'Sauerkraut' is an ancient process of fermenting cabbage that was used to preserve as a source of vitamins and minerals during the winter months. Similarly, 'Kimchi' is a traditional Korean dish prepared from the mix of vegetables like napa cabbage, radish, scallion or cucumber with a variety of seasonings. Cabbage leaves, which are typically a light to medium green color, are low in fat and high in fiber, protein, vitamins A, C, B6, K and folic acid. They have medicinal properties as well and are used by breast feeding mothers to help reduce engorgement.

Cabbage cultivars are red, purple or more commonly green. Cabbage consisting of a terminal stem and densely packed leaves is actually a biennial with a life cycle of two years; however, it is grown and harvested as an annual.

2.5.2.1 Origin

Cabbage is believed to have evolved from a wild form native to Europe and to the Mediterranean region of the world.

2.5.2.2 Soil requirement

Cabbage prefers full sun and thrives well in organic matter such as compost or manure. The soil should be moist well-drained at least average to fertile enriched with humus. Light sandy soil is good for early crops. The seedlings should be planted about 12 to 24 inches apart to the same depth and level as they came in their pots before transplanting them. The further apart you plant the cabbage, the larger the head will develop. Cabbage likes a fertilizer that is high in nitrogen since the green foliage is encouraged to grow more.

2.5.2.3 Climate

Cabbage is a cool season crop thriving in cooler temperatures. It is one of the earliest crops that can be planted in the spring, but not too early. Cabbage plants will survive a hard frost but not a freeze. Several days or nights of continuous colder temperatures will cause 'bolting' where an elongated terminal stem produces ultimately giving a seed head.

2.5.2.4 Planting

Keep the soil cool using mulch straw. When the head start to form mound the earth up against the stems to help stabilize the plants. Smaller Head Cabbages (*Capitata* group) that mature early should be spaced 35 cm apart while the larger, late kraut varieties need up to 80 cm of space between each other. Water them right after planting and frequently avoiding saturation. Very shallow cultivation every couple of weeks is good to weed eradication. Cabbage is one of the exhaustive crops. So a 5-10-5 fertilizer should be dusted between the rows a month after planting at 12 kg per 10 sq. m. It should be watered in well. In *Brassica Pekinensis,* the whole plant is cut. Trimmed heads will stay good for 2 to 3 weeks if refrigerated in a plastic bag.

2.5.2.5 Propagation

Spring crops from *Capitata* group may be started by planting hardened off transplants early. For fall or winter crops, seeds may be sown outdoors, in late summer. Those that mature fast are recommended for spring planting. Sowing seeds in *Pekinensis group* is late summer or fall which will produce large, good quality heads. Heads can be protected from light frosts, but will be killed by hard freezes. All Chinese Cabbages are hard to transplant, because any stress seems to stunt their growth. Use peat pots if starting indoors. Direct seed *Chinensis group* in early spring and again in late summer. Pak-choi is difficult to transplant except when the seedlings are very small. Spray once in a season to discourage Cabbage worms.

2.5.2.6 Varieties

(Capitata group) Early: Golden Acre; Darkri. Midseason: King Cole; Greenback; Roundup; Blue Ribbon.

Late: Blue Boy; Rio Verde, Grand Slam.

Savoy: Savoy King.

Red Cabbages: Preko. (Pekinensis group) Spring A-1; Jade Pagoda; Tropical Delight; Michihli. (*Chinensis* group) Joi Choi; Lei Choi

Copenhagen market, Green stone, Drum head, Green coronet are the cultivars grown in Nepal while Bartolo, Castello and Rovite (red cabbage) are the cultivars grown in Norway.

2.5.2.7 Harvesting and Storage

Harvest the heads when they are large, solid and firm to the touch, usually about 2 to 3 months after planting, depending on the variety. Generally, heads intended for fresh market are hand-harvested, while those destined for storage or sauerkraut are mechanically harvested. To harvest the cabbage, twist the entire head of the cabbage to disengage it from the large cabbage stem. Remove loose or yellow leaves from the heads and store under cool conditions 0 °C with 100% humidity is ideal. Late crop cabbage can be stored for 5 to 6 months. Early crop cabbages have a shorter storage time, typically only a month. Wrapper leaves are trimmed and heads are sorted and packed into crates or cartons and cooled to 0 °C. Vacuum cooling, rather than slurry ice is used to cool cabbage and cauliflower.

2.5.2.8 Pests and Diseases

Cabbage worm is a common problem which is bright green worm that eats large ragged holes into the cabbage leaves and infest the heads, all the while blending in perfectly. These worms later develop into white or pale yellow butterflies with three or four spots on their wings. A spray of a bacterial insecticide containing *Bacillus thuringensis* to keep pests at bay is recommended. Another common disease for cabbage is yellow or fusarium wilt. Yellowing or browning of the outer and lower leaves marks the disease of yellow or fusarium wilt caused by over-watering or insects' infestation or lack of seed treatment prior to sowing. Collect the leaves, stems and tops and burn to dispose them to prevent the spread of the disease on the rest of your garden.

2.5.3 Kohlrabi (*Brassica oleraceae L. var gongyloides*)

Kohlrabi; an erect, swollen stem that forms a turnip-like spherical swelling slightly above the surface of the soil, is regarded as a close relative of Cabbage also known as Italian Turnip and Stem Turnip. The edible portion of kohlrabi is a shortened and swollen basal stem called a bulb. The foliage grows from the bulb on long stems and resembles the leaves of Cabbage. There are purple- or green-skinned varieties and they both have a greenish-white interior. These plants are ready to eat only a few weeks after sowing.

2.5.3.1 Planting

Plants should be 25 cm apart in rows that are at least 65 cm apart. The soil should be fertile and moist to maintain the rapid growth required to form tender bulbs that are free of strings and pith. At harvest time, the whole plant is pulled up. Trim off the leaves and thick taproot. The bulbs can be eaten raw or peeled, diced and cooked with the tender, young foliage.

2.5.3.2 Propagation

Sowing of seeds can be done either in early spring or in late summer. Summer plantings are possible in cool climates.

2.5.3.3 Varieties

Rapid is a good early variety. Grand Duke is a midseason green hybrid. Purple Danube is an improvement over the old Purple Vienna. We grow Korridor, Kordinal and Kolibri (purple cultivar) in Norway.

2.6 Post-harvest

The quality of vegetable is of paramount importance in order to meet consumer demand and to be competitive in the global market. Marketing of vegetables have several features different from that of some other agricultural products as fruits, berries and nuts. Perishability is one of them. Vegetables are living tissues that are subject to continuous changes after harvest. Because of their characteristics (high-moisture content, large size, rapid rate of metabolism), they can deteriorate rapidly after removal from the plant. Vegetables are more delicate and succulent products which can easily be degraded in terms of visible and non-visible physical and nutritional quality. Additionally, Brassica vegetables such as cauliflower, cabbage and kohlrabi are highly perishable due to their high respiration rate. In this situation, the postharvest technology can be the better way to keep the produce with possible minimum loss in quality and quantity (Shukor et al. 2003). If the produce has long shelf-life, it can get the competitive price as stated by (Ekman 2006). The deterioration and significant economic loss in case of perishable products like vegetables comprises mainly due to the improper handling of vegetables after harvest. Postharvest losses vary depending on several factors such as improper handling and packaging, low-level technology, lack of basic equipment and facilities at the collection centers or packing houses and lack of trained personnel are prevalent limitations in case of growing vegetables in most of the developing countries. This loss has been observed to vary between 20-50% in developing nations. In some instances, this loss can even exceed 50%, depending on the handling and distribution chain which vary with different countries (Shukor et al. 2003). Delays between harvesting and cooling or processing can result either in direct losses due to water loss and decay or indirect losses such as loss in flavor and nutritional quality (Lee & Kader 2000). Grading standards, packaging and processing information are very basic things to be considered to facilitate quality marketing (Rangkadilok et al. 2002).

Obviously, time, temperature, humidity and gas conditions are very important parameters for maintaining quality after harvest. In this respect, transport and storage are very important steps in the logistic chain between harvest and consumer's purchase (Verkerk et al. 2009). Cauliflower like its biological relative broccoli belongs to the vegetables of a high perishability.

Hence, it is pertinent to evaluate the postharvest handling chain of vegetables taking in account of the different factors involved in a holistic manner in order to identify the causal factors in postharvest losses and provide appropriate control measures. Post-harvest horticulture deals with the technology to slow down the rate of metabolism of the produce without enhancing the abnormal events within the produce. It is the last stage within the gradual process of producing high quality fresh marketable products from the field to the dinner table confronting many challenges. A farmer who addresses these challenges, can expand his or her marketing opportunities to compete the convenient market (Suslow & Cantwell 1999).

2.6.1 Temperature

Temperature management is the most crucial tool to enhance the shelf-life and maintain quality of fresh vegetables. Temperature is associated with the respiration of the products; high storage temperature leads to the weight loss in the produce due to high rate of respiration ultimately getting the produce shriveled and wrinkled. The lower temperature also lowers the respiration rate thus the metabolism within the produce. The minimizing of all the developmental processes such as respiration, transpiration within the produce is the key factor to increase the shelf life of the produce. Since harvested produce doesn't have any source to replenish the loss of substrates from respiration and loss of water from transpiration, it is of prime importance to lower the respiration and transpiration rate to the minimum possible as they are both responsible for the quality deterioration. The important consideration in lowering storage temperature requires the thorough knowledge of the temperature sensitiveness of the produce as chilling sensitive crops cannot bear very low temperature. Accelerated losses in vitamin C usually occur at higher temperatures in many types of fruits and vegetables. The vitamin C contents (mg/100g) of cauliflower were 48.4, 45.75, 29.04 and 25.3 at initial, 3rd, 6th and 9th days of storage respectively (Jany et al. 2010). However, some chilling sensitive crops are heavily affected at lower temperatures (Lee & Kader 2000; Wills et al. 2007). The freezing point ranging from -2°C to 0°C is the lower limit of the produce while the collapsing point (about 40°C) of the plant tissues is the upper limit to be maintained at post-harvest. The best keeping quality is obtained by

the storage and handling just above its freezing point or just above its chilling threshold temperature in case of chilling-sensitive produce (Wills et al. 2007).

At normal temperature, the shelf life of cauliflower was 10 days, 18 days stored in refrigeration and further increased to 30 days upon storage at freezing condition. Similarly, cabbage also expressed the same 30 days as cauliflower upon freezing storage while it was 20 days in refrigeration and 12 days at normal temperature. Thus, freezing storage seemed the best storage among these three discussed in both crops (Jany et al. 2010). (Raja et al. 2011; Romo-Parada et al. 1989) reported that the post-harvest life of cauliflower was 3-4 weeks at the common commercial storage condition of 0°C and 95-100% RH.

After 12 days storage of cabbage at 4°C, the color, flavor and texture changed to black, spoiled and very soft respectively while in case of cauliflower; color, flavor and texture changed to blackish, spoiled and firm curd respectively (Jany et al. 2010).

2.6.2 Relative Humidity (RH)

It is very crucial to maintain the high relative humidity reducing the vapor pressure deficit (VPD) of atmosphere around the storage of the produce to minimize the water loss ensuring no shriveling and wilting. It is advised to maintain a RH above 95% for leafy vegetables and some root vegetables because they have very high coefficients of transpiration. The microbial growth is one of the problems of low temperature storage of the produce which should be considered and avoided.

Spraying of the mist of water to the atmosphere is the simple way to increase RH.

2.6.3 Controlled Atmosphere (CA)

Controlled atmosphere is the composition of gases in the storage atmosphere which affects the storage life of the produce. The storage life can be increased by altering the concentration of oxygen and carbon dioxide, the respiratory gases of the produce. It is based on the principle that glucose in the presence of oxygen burns to release carbon dioxide and water during the process of respiration. Herein, limiting oxygen and elevating carbon dioxide slows down the metabolism. Dewey et al. (1969) reported to lower the O_2 levels by 2% and increase the CO_2 levels by 5% in case of cabbage, Brussels sprouts, Cauliflower. Development of off-flavors and off-odors happens due to very low oxygen concentration leading to anaerobic respiration and very high carbon dioxide level leading to fermentative metabolism. The increased carbon dioxide above 1% and decreased oxygen levels down from 8% from the normal atmospheric composition (CO_2 0.33% and O_2 21%) has been found to be beneficially affecting the metabolism of the produce since many years research. Ethylene has also been found to adversely affect the post-harvest life of the produce by enhancing abscission, ripening and senescence (Wills et al. 2007). The concentration of O_2 levels ranging from 2% to 8% and CO_2 levels less than 5% has been recommended in maintaining the quality attributes in cauliflower during storage (Raja et al. 2011). The salability of fresh cauliflower has been found to be increased up to 52 weeks by the storage under CA of 3% O_2 and 3-5% CO_2 (Romo-Parada et al. 1989). But the O_2 levels below this and CO_2 levels above 5% is favorable to develop different storage disorders and/or tissue damage (Kalra et al. 1984; Voisine et al. 1993). The research of Ekman & Golding (2006) has reported that broccoli could be successfully stored for a maximum of 3 weeks in crushed ice, 4 weeks in humidified air or 5 weeks under a controlled or modified atmosphere with good quality and adequate shelf life. On the other hand, the storage life of cauliflower was increased from 4 weeks to 5 weeks by storage in 2% O_2 + 2% CO_2.

ACC synthase (key regulatory site of ethylene biosynthesis) is inhibited by the elevated CO_2 atmospheres while ACC oxidase activity is stimulated at low CO_2 and inhibited at high CO_2 concentrations and/or low O_2 levels. Similarly ethylene action is also inhibited by elevated CO_2 atmosphere. Optimum atmospheric composition inside the storage retard chlorophyll loss (green pigment), biosynthesis of carotenoids (yellow and orange color) and anthocyanins (red and blue color) and biosynthesis and oxidation of phenolic compounds (brown color). Reduced O_2 and

elevated CO_2 atmospheres also influence flavor by reducing loss of acidity, starch to sugar conversion, sugar inter-conversions and biosynthesis of flavor volatiles. Retention of ascorbic acid and other vitamins also result in better nutritional quality in an optimum atmosphere (Kader 2003).

The accumulation of many volatile compounds such as ethylene produced over certain critical levels enhance ripening and senescence thus reducing the storage life. So it should be controlled. The products will get more susceptible to decay when the fruit is physiologically injured by too low O_2 or too high CO_2 levels. Physiological disorders arise as a result of adverse postharvest and pre-harvest environmental conditions or mineral imbalances arising during growth; and microbial decay from many bacteria and moulds infecting the produce before and after harvest.

2.7 Storage

There is good scope for the stored vegetable in present situation since the population is increasing in the geometric pattern while the production of the crop has been decreasing. Besides, the productive land is being converted into the uncultivable land due to the use of land for housing and other road infrastructures. So, this situation compels us to challenge to feed the increasing population. Thus, we need to seek alternative ways to keep the population away from the hunger. In this case, there should either be an increase in the production by increasing the productive land or by rationally using the produced products sustainably, ensuring the conservation for the future. This situation leads to the invention of the postharvest technology, which deals on how to preserve the surplus products with minimum loss.

There are many factors that affect the quality of the stored vegetables. The storage of horticultural produce is based on a principle that the quicker the temperature of the produce is reduced to the optimum storage temperature, the longer its storage life (Wills et al. 2007). For example, if the cauliflower are stored at more than 5% CO_2 than it will develop the off odors and flavors resulting stem injury (Ekman 2006). But the development of quality deterioration may not be detected immediately after storage, they may develop at the time of cooking (Lipton et al. 1976).

Variety, growth conditions and time of harvest, maturity at harvest, post-harvest storage conditions and the industrial processes are the prime factors responsible for the variation in the composition of the plants (Podsedek 2007). It may not be always true because the nutrient content though of the same species may have significant difference depending upon the parts of the crop. Moreover, a lot of changes in the nutritional properties and quality are associated with the storage. During the storage period, changes in the chemical composition of their curds progress very fast under conditions of controlled atmosphere (Hansen et al. 1995). The cabbage in storage is found to have the deterioration of the stem or seed stalk growth (bolting), root growth, internal breakdown, leaf abscission, discoloration, decay and black speck. Long-term storage usually results in extensive trimming of heads to get detached deteriorated leaves. Apart from physical losses, physiological losses occur during storage such as loss in weight, loss of firmness, alteration in sensory attributes as flavor. The most important change is in the nutritional qualities. Storage of

green vegetables like cabbage is often associated with the loss of antioxidant compounds. The quality attributes of economic importance in broccoli such as Ascorbic acid has shown a remarkable change depending on storage time, temperature and packaging by a decrease up to 70% (Podsedek 2007). The research conducted on broccoli cultivars under storage revealed that the antioxidant activity and vitamin C content were both increased in comparison to the fresh florets while the controlled atmosphere expressed no significance (Wold et al. 2004).

Cauliflower is extremely perishable. Thus, freshly harvested fruits and vegetables contain higher amount of LAA than subjected to storage and Cauliflower depicts a gradual decrease in LAA as the storage temperature or duration increases. The convenient commercial storage conditions of cauliflower for retaining the quality attributes at minimal loss should be between 0-4°C while that is stated to be at 0°C and 95–100% relative humidity for an expected shelf life of 3–4 weeks. The content of LAA and Total Soluble Solids (TSS) were found to be decreased when stored at 2 ±1°C (Raja et al. 2011).

Based on the research conducted to study the pre- and post-harvest factors influencing the Vitamin C content of some horticultural crops during storage, (Lee & Kader 2000) recommended to keep the O_2 levels of between 2-8% and CO_2 levels less than 5% during storage. Vegetables were categorized into the high retention (>95%) for broccoli, Brussels sprouts; medium retention (65-70%) for green pea, spinach, turnip; and low retention (5-30%) for asparagus and green beans according to the intensity of AA retention. Vegetables which report high AA retention contained high amounts of total sulfur and glutathione where glutathione may be involved in the reduction of Dehydroascorbic acid (DHA) to AA in crucifers. Hence minimum loss has been observed in cruciferous vegetables than the non-crucifers (Albrecht et al. 1990). According to the findings of (Rangkadilok et al. 2002; Rodrigues & Rosa 1999); refrigeration (4°C) and freezing are the most effective means of maintaining shelf life of the produce. The storage at high temperature rapidly causes deterioration of cauliflower quality and shelf life. Cauliflower should be harvested either early in the morning or in the evening to avoid shock. Cauliflower when allowed to roll over and white curd touching any surface will result in decay and browning (Boyette 1996)

2.8 Nutritive Properties

Cole crops are regarded as the important vegetables because of their high nutritive and dietic values as they possess high amounts of vitamins (Heimler et al. 2006). A necessity of consumption of fruits and vegetables by human beings has been at all times to satisfy nutritional needs, particularly for essential vitamins and minerals (Maggioni et al. 2010). The average consumption of green vegetables per capita per day is 307g amongst which the major portion is in part of Brassicas (Lewis & Fenwick 1987). Though, the overall consumption is relatively low in developed nations of Northern Europe and North America as documented by World Cancer Research Fund/American Institute for Cancer Research (Hansen & Wold 2008) and is far beyond expectancy in developing nations. The dwellings there are long striving under malnutrition getting the victims of marasmus and kwashiorkor. In addition to the nutritional value of vegetables, vegetable production, with its increasing overall share of world food production, has an important economic significance in developing countries. The importance of the vegetable industry in these developing countries as a potential source of foreign exchange has been long recognized (Nepal 1995).

Those crops are rich in chemical composition which is derived from the edible part. Wide range of vitamins, minerals, fiber and carbohydrate can be obtained from the Cole crops. They provide high amounts of vitamin C, soluble fiber and multiple potential anti-cancer nutrients. Among them, the most important from dietary point of view is the antioxidant property. They are also a good source of carotenoids in which broccoli is exceptionally rich. Cauliflower attributes our health with its high dietary fiber, folate, water and vitamin C and low fat content. Though broccoli possesses high nutritive contents, cauliflower is a close relative of it. Both are designated as the same variety of the cruciferous family containing not only the nutritive value of Vitamin A, Thiamine, Riboflavin, Niacin, Vitamin C, Calcium, Iron, Phosphorous and Fat to help fight diseases but also sharing the wonderful photochemical (Trezza & Krochta 2000).

Consumption of vegetables in the developing region is expected to steadily increase with variations among the different countries based on their per capita and availability (Ruel et al. 2005). In estimating the amount required for the perfect anti-carcinogen effect, epidemiological studies have revealed that the ingestion of three or more half-cup servings of cruciferous

vegetables such as broccoli, Brussels sprout, or cabbage per week significantly lowered the risk for prostate cancer by 40% compared to ingestion of one or fewer servings per week (Cohen et al. 2000). Epidemiological studies have associated these vitamins with a reduced risk of several types of cancer (Ramos et al. 2011). However, under the right conditions, these compounds may also act as pro-oxidants as seen for *â*-carotene in several recent studies (Kurilich et al. 1999).

Besides the nutritional importance of the fruits and vegetable, they also act as bioactive compounds. Bio-active compounds are the chemical constituents present in fruits and vegetables in small concentrations and are effective in low concentrations. They are believed to prevent, delay or cure different diseases.

2.8.1 Vitamin C

Vitamin C constitutes L-ascorbic acid (LAA) and Dehydroascorbic acid (DHA), is a water-soluble vitamin inferring that our body neither synthesizes nor stores it. Hence, we must fulfill what we need, instead, from our regular food. Therefore, Vitamin C must be obtained from the dietary source (Chen et al. 2003). Humans require vitamin C for metabolizing the various nutrients in the body and the growth and repair of tissues in all parts of our body. Further, it helps the body to prepare collagen, an important protein used to make skin, cartilage, tendons, ligaments, and blood vessels. Vitamin C also plays an important role in healing wounds and repairing and maintaining bones and teeth. Thus, Vitamin C acts as an enzyme co-factor, a radical scavenger and either as a donor or acceptor in the electron transport at the plasma membrane (Cartea 2011). Only about 50 mg of Vitamin C per day is necessary to prevent scurvy, a disease caused in its deficiency (Wills et al. 2007). Fruits and vegetables are the main sources of the vitamin C for human body. The dominating citrus fruits such as orange, lemon, sweet orange etc. are main sources of Ascorbic acid. Vitamin C is found mostly in fruits and vegetables, where the highest concentrations are in fresh, raw foods while whole grains, seeds, or beans contain very little Vitamin C, except when they are sprouted, which raises the ascorbic acid content. It is exclusively found in considerable amount in the many fruits, vegetables and berries etc. in the form of almost ¾ L-ascorbic acid (AA) and ¼ Dehydroascorbic acid (DHA). Due

precaution is required to handle AA as it is highly unstable in the sample because it can be oxidized by oxygen to Dehydro-ascorbic acid.

Fruits and vegetables constitute the varying levels of vitamin C as an influence of various factors. Among Brassicas, Broccoli and Brussels sprouts contain the highest amount of Vitamin C (100 mg/100g) followed by cabbage containing (35 mg/100g) and cauliflower with comparatively low concentrations (Wills et al. 2007). Among them, genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures are the dominating ones. The higher the intensity of light during the growing season, the greater is vitamin content in plant tissue. On the other hand, Nitrogen fertilizers at high rates tend to decrease the vitamin C content in many fruits and vegetables. Less frequent irrigation can be employed to increase the content of Vitamin C (Lee & Kader 2000).

The pre-dominating level of Ascorbic acid in Cruciferous vegetables acts as antioxidants, the compounds having a property that may protect against several degenerative diseases such as cancer and osteoarthritis (Lampe & Peterson 2002; Vallejo et al. 2002). Variability in vitamin content among the broccoli cultivars suggest that potential health benefits that accrue with consumption are genotype dependent. Cruciferous vegetables, including subspecies of *B. oleraceae* such as Brussels sprouts, cabbage, kale, cauliflower, kohlrabi and broccoli are relatively abundant sources of antioxidants with potential anti-carcinogenic activity.

Cooking can destroy much of the Vitamin C content in food and it is easily oxidized in air and is also sensitive to light. Being mostly contained in the watery part of fruits and vegetables, Vitamin C is easily lost during cooking in water. The steaming of vegetables minimizes its loss.

2.8.2 Antioxidants

Oxygen, an indispensable element for the existence of life, can under some conditions, adversely affect the human beings. Oxidation is essential part of metabolism in human body. At the same time, the uncontrolled formation of reactive oxygen species (ROS) is due to the potentially

harmful effects leading to the unbalanced mechanism of antioxidant protection, governs the onset of many chronic and cardiovascular diseases and enhance aging (Koksal & Gulcin 2008; Liu 2003). ROS are a group of highly reactive molecules formed during aerobic mechanism in the living beings and contain superoxide anion radicals (O_2), hydroxyl radicals and non-free radicals as single oxygen and H_2O_2 (Gulcin et al. 2002; Halliwell & Gutteridge 2007). The key role of antioxidants is to balance among generation of ROS and inactivation of ROS. If balance could not be maintained, ROS leads to the oxidative modification in cellular membranes or intracellular molecules (Duh et al. 1999). Antioxidants are believed to be the possible protective agents reducing oxidative damage from ROS in the human body and retarding the onset and progress of many chronic diseases and lipid peroxidation (Kinsella et al. 1993; Pryor 1991). Therefore, it has been a keen interest in fruits and vegetables as a supplier of antioxidants to humans and animals either as a food component or as certain pharmaceuticals. Antioxidants, the phytochemicals that inhibit or delay the oxidation of other molecules by hindering the initiation or propagation of oxidizing chain reactions (Velioglu, Y. et al. 1998).

In short, the bioactive compounds found in plants and plant products possessing anti-carcinogenic activity including other phytochemicals preventing oxidation are defined as Antioxidants. They can delay, induce or prevent the oxidation of polyunsaturated fatty acids by scavenging the free radicals and reducing oxidative stress (Dai & Mumper 2010). Antioxidants are parts of the human body defense system against free radicals and neutralize them by donating one of their own electrons (Kaur, Charanjit & Kapoor, Harish C. 2001). The most likely and practical way to fight against degenerative diseases as a consequence of free radical damage is to improve body antioxidant status which could be achieved by higher consumption of vegetables and fruits. Among the vegetables, Brassica crops are the ones having the highest antioxidant activity (Soengas et al. 2012; Zhou & Yu 2006). The low dietary intake of fruits and vegetables by a person doubles the risk of major types of cancer as compared to excess intake and at the same time also markedly increases the risk of heart disease and cataracts (Ames et al. 1993). Among dietary antioxidants, red cabbage and Brussels sprouts are the prominent sources (Podsedek et al. 2006). The bodily defense mechanism through antioxidant phytochemicals from Brassica crops has been greatly assigned to antioxidant vitamins comprising ascorbic acid, α-tocopherol and β-carotene (Prior & Guohua 2000). These antioxidants together with other attributes have the potential to prevent and treat malignant diseases (Byers & Perry 1992). The imbalanced state

where excessive quantities of reactive oxygen species (ROS) and reactive nitrogen species (RNS) lead to the oxidation of enzymes, proteins, DNA and lipids and other biomolecules is said to be the oxidative stress (Dai & Mumper 2010). This stress is significant in the development of chronic degenerative diseases including the coronary heart disease, cancer and aging (Ames et al. 1993).

The damage in DNA, protein and lipid is a major contributor to aging and ultimately leading to the degenerative diseases of aging such as cancer, cardiovascular disease, immune-system decline, brain dysfunction and cataracts (Liu & Mori 1999). Antioxidant defensing property against this damage includes ascorbate, tocopherols, and carotenoids. Foods from plant origin usually contain natural antioxidants that can scavenge free radical. Three major antioxidant nutrients are vitamin C, vitamin E and b-carotene. Just because of these different antioxidants present in Brassica vegetables, they are considered as the most interesting crops from consumer's point of view too (Cartea 2011). Red cabbage being the richest source of dietary antioxidants bearing its high antioxidant activity (6-fold) and vitamin-C (2.5 fold) compared to its kind (white cabbage) (Podsedek et al. 2006). Intake of these nutrients has an inverse relationship with the risk of age-related chronic illnesses such as degenerative and cardiovascular diseases (Kris-Etherton et al. 2002) and various types of cancer (Wang et al. 2004). Antioxidants are believed to have a positive effect on human health and related to the positive effect of a diet rich in fruits and vegetables. These naturally occurring compounds impart bright colour to fruits and vegetables and act as antioxidants in the body by scavenging harmful free radicals, which are implicated in most degenerative diseases. These brassica vegetables are to be thanked for possessing such attributable compounds of great value in terms of human health (Cartea 2011).

The antioxidant activity of Brassica crops varies depending upon crop species, plant age, and plant part taken into account and in some instances, the method of analysis too. Additionally, the difference to some extent is also governed by the difference in total phenolic content and their composition (Soengas et al. 2012). The antioxidant activity of white and Chinese cabbage according to Samec et al. (2011) was reported to be the highest at the juvenile stage Podsedek (2007) states that the major antioxidants of Brassica crops are primarily attributed to the phenolic compounds. In a research carried out to observe the significant stage to obtain the highest antioxidant activity analysis for cauliflower, broccoli sprouts, cabbage, kale and nabicol revealed

the highest antioxidant activity in cauliflower followed by broccoli (Soengas et al. 2012). Moreover, it reveals that there is an increase of antioxidant activity of Brassica crops with time from sprouts till reaching its three months after sowing which in turn gradually declines. Hence, it concludes that the maximum antioxidant activity reaches when the leaves are young. In another study, Samec et al (2011) agreed that the antioxidant activity of white and Chinese cabbage leaves increased until full maturation (first 8-12 weeks) and expressed a decline trend. The richest antioxidant activity in kale has been mentioned by different findings compared to other Brassica vegetables as Brussels sprouts, broccoli, cabbage, cauliflower and most common vegetables such as pepper, beets, onion, garlic, celery, cucumber, spinach, carrot, potato, rhubarb or green beans (Cao et al. 1996; Zhou & Yu 2006). Similarly, the study conducted by (Nilsson et al. 2006) illustrated at least 10-fold higher antioxidant activity in curly kale than that of cauliflower and white cabbage which is the highest compared to its kind of other Brassicas as Brussels sprouts, broccoli, green cauliflower (Romanesco) though broccoli is the most deeply studied cole crop for its reasonably higher antioxidant activity and phenolic composition (Podsedek et al. 2006).

2.8.3 Phenolic Compounds

Phenolic compounds are the bioactive, non-nutrient and most important group of phytochemicals which are often responsible for the bright reds and blues in berries and vegetables. There are thousands of phenolic phytochemicals grouped into two main categories polyphenols and flavonoids out of which polyphenols, flavonoids, anthocyanin, hydroxycinnamic acids, isoflavones, flavones, catechin, isocatechin etc. are the major ones. The first one predominate tea and red wine polyphenols. Choi et al. (2004) recommends drinking 1-2 glasses of red wine every day. The major and commonly widespread polyphenol in Brassica species are flavonoids acting as free radical scavanging and hydroxycinnamic acids possessing the catechol-type structure as caffeic acid (Croft 1998). Flavonoids is the major polyphenol to express bright colour in berries, apples and other vegetables thus attract pollinating insects and also protect from damaging oxidation by lipid and vital cell constituents. Anthocyanin is the dominating phenol in red cabbage imparting deep red color and also possessing dramatically high amounts of antioxidant activity compared to other cabbages.

The roles of the antioxidants derived from fruits and vegetables including red wine whose credit has been accredited to their phenolic compounds as one of the constituents. Many contemporary studies this time have discussed and concluded that vitamins C or E derived from the dietary sources of plants are more effective antioxidants in vitro than their significant protective role in vivo (Rice-Evans et al. 1997). Though hydroxycinnamic acids are the major phenolic compounds in many vegetables, anthocyanin are the main constituent in red cabbage (Podsedek et al. 2006). 23 different anthocyanins of highly conjugated with sugars (glucose and xylose) and acylated groups (caffeoyl, p-coumarolyl, feruoyl, p-hydroxylbenzoyl, sinapoyl and oxaloyl) as cyanidin derivatives are found in red cabbage (Wu & Prior 2005b) whereas white cabbage comprises of a mix of more than 20 phenolic compounds such as glucosides of kaempferol and quercetin acylating with the hydroxycinnamic acids or not (Nielsen et al. 1998).

2.9 Bio-active compounds

The main bioactive phytochemicals present in fruits and vegetables are polyphenols, terpenoids, glucosinolates, and other sulfur-containing compounds (Raja et al. 2011). Researches show that these cole crops are rich in indole-3-carbinol, a chemical compound which boosts DNA repair in cells and appears to block the growth of the cancer cells. Those substances in the crop have the beneficial properties for our health including the phenolic compounds, ascorbic acid, β-carotene and α- and β-tocopherols and glucosinolates (Singh et al. 2007).

A range of volatile and non-volatile products as a product of the compounds that may be broken down by an enzyme, thioglucoside glucohydrolase also called myrosinase (Lewis & Fenwick 1987). Studies reveal that amino acids are the derivatives of the glucosinolates which mostly lie on a common biosynthetic pathway. Typical brassica flavor is attributed in considerable degree to glucosinolates derived from volatile iso-thiocyanates and nitriles (Lewis & Fenwick 1987). Of the glucosinolates found in calabrese, only those possessing prop-2-enyl, 3-methylsulphinylpropyl and 4-methylsulphinylbutyl chains would be expected to produce such products. Thus, compared with cabbage, Chinese cabbage and Brussels sprouts, calabrese would be expected to be considerably less strongly flavored and to be less pungent. In addition, bitterness, a flavor defect in certain Brussels sprouts (Fenwick et al., 1983b), has been linked to high levels of prop-2-enyl and/or 2-hydroxybut-3-enylglucosinolates and would seem to be unlikely to be associated with calabrese (Lewis & Fenwick 1987).

The beneficial phytochemicals for human health present in cauliflower for example sulforaphane which is released upon chewing or chopping. Cauliflower also contains other glucosinolates besides sulforaphane, substances which may improve the liver's ability to detoxify carcinogenic substances. Therefore, a high intake of cauliflower has been found to reduce the risk of aggressive prostate cancer (Schuurman et al. 1998). In addition, the compound indole-3-carbinol, which appears to work as an anti-estrogen, appears to slow or prevent the growth of tumors of the breast and prostate.

According to (Drewnowski & Gomez-Carneros 2000), the major glucosinolates in cauliflower were those containing prop-2-enyl-, 3-methylsulphinyl propyl-, 3-indolylmethyl- and 1-methoxy-

3-indolylmethyl side chains. In that study, the latter two compounds, together with 4-methylsulphinylbutyl glucosinolates, predominate. In case of cauliflower, 3-indolylmethyl glucosinolates (range 7"2-78-9 mg 100 g^{-1} fresh weight) was present in much larger amounts than its 1-methoxy analogue (range 0.6-16"5mg 100g^{-1} fresh weight).

Rather more importantly, researches in a number of laboratories (Lewis & Fenwick 1987) have demonstrated that anti-carcinogenic and enzyme-inducing effects of *Brassica* vegetables are due primarily to indole glucosinolates breakdown products. Calabrese would seem to be comparable to cauliflower and swede as a source of indole glucosinolates, being especially rich in 1-methoxy-3-indolylmethyl glucosinolates, the biological properties of which, along with those of its hydrolysis products (Lewis & Fenwick 1987).

2.9.1 Glucosinolates

The organic compounds containing sulfur and nitrogen derived from glucose and synthesized from certain amino acids are called glucosinolates. The molecule comprises a b-thioglucoside N-hydroxysulphate, containing a side chain and a β-D-glucopyranose moiety (Cartea & Velasco 2008). The basic glucosinolate structure consists of a cyano group and a sulfate group (Figure 3).

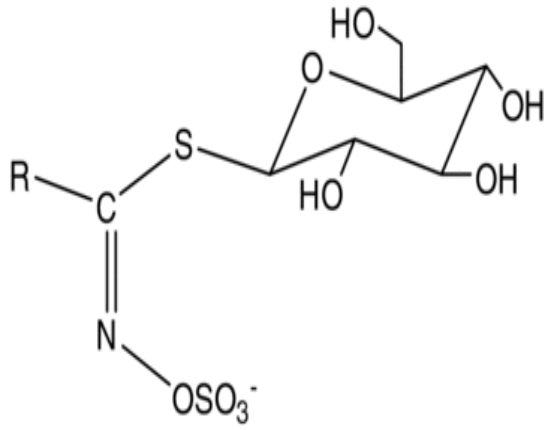

Figure 2. The basic structure of glucosinolates (Zrybko et al. 1997)

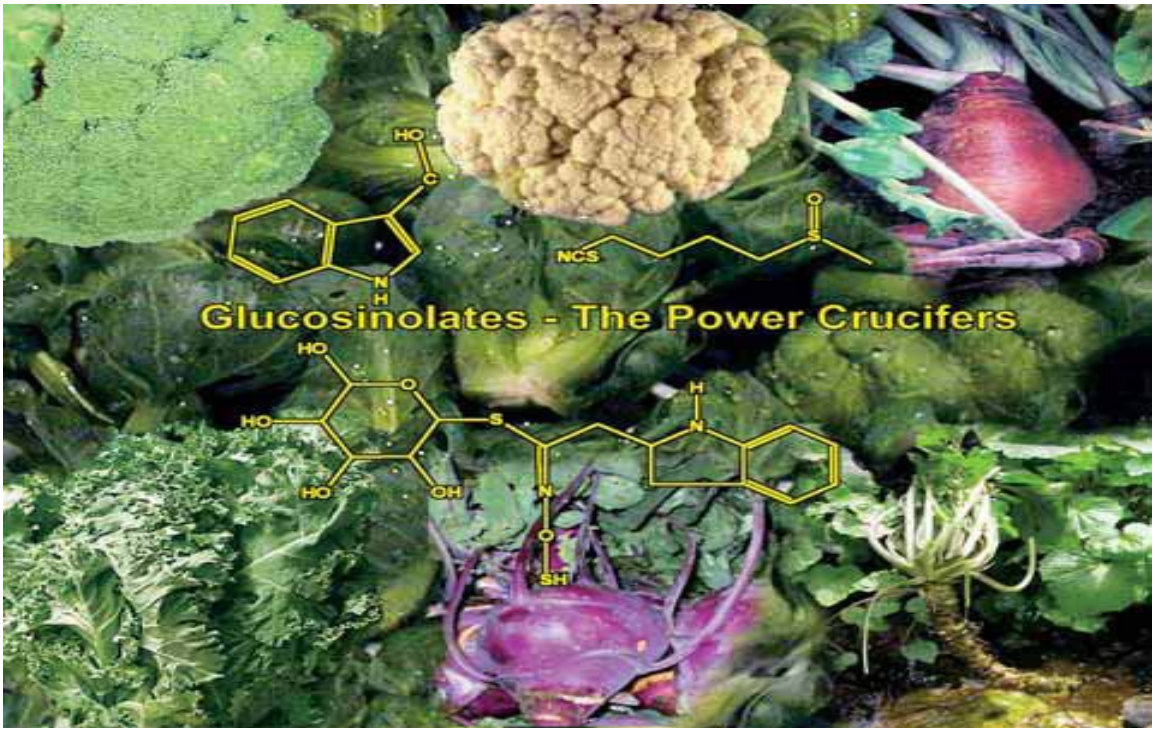

Figure 3. The crucifers as a donor of antioxidants (Kaur, C. & Kapoor, H.C. 2001)

The cruciferous vegetables as a group (Figure 3) contribute to more cancer-inhibiting phytochemicals; the most powerful being the glucosinolates, to the human diet compared to any other groups of fruits and vegetables.

These sulfur and nitrogen containing glucosides may be hydrolyzed by myrosinase (thioglucoside glucohydrolase) to yield glucose, sulfate and aglucones that can ultimately sequence fragmentation and molecular rearrangement to form volatile and non-volatile products such as isothiocyanates, thiocyanates, indoles and nitriles according to the available conditions (Mithen 2001). Chewing and cutting as a process of disruption result in hydrolysis of myrosinase and the glucosinolates as they are physically detached from each other in plant cells (Verkerk et al. 2001). They occur as secondary metabolites of almost all plants of the Brassica exclusively in dicotyledonous plants. The highest concentrations are found in the Brassicaceae family. Over 120 different glucosinolates have been identified to this date out of which only a few in numbers have been investigated thoroughly (Verkerk et al. 2009). Human foods and feeding stuffs were extensively employed as the varying levels of glucosinolates (also known by their historical name, mustard oil glycosides).

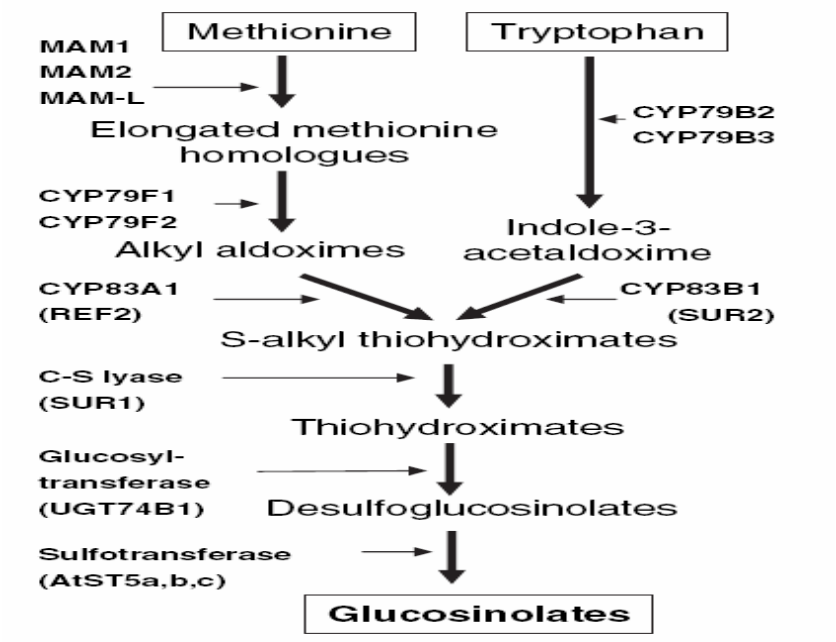

Figure 4. Biosynthesis of glucosinolates (Ellerbrock et al. 2007)

This figure 2 shows the process of biosynthesis of glucosinolates from precursors (amino acids) methionine and tryptophan undergoing various transformations in the presence of enzymes glucosyltransferase and sulfotransferase.

Glucosinolates can be grouped into three chemical classes based on whether their precursor amino acids which are enlisted as:

(A) Aliphatic Glucosinolates (Alkyl-amino acid methionine)
(B) Aromatic Glucosinolates (Phenyl- amino acid tryptophan)
(C) Indole Glucosinolates (tyrosine or phenylalanine)

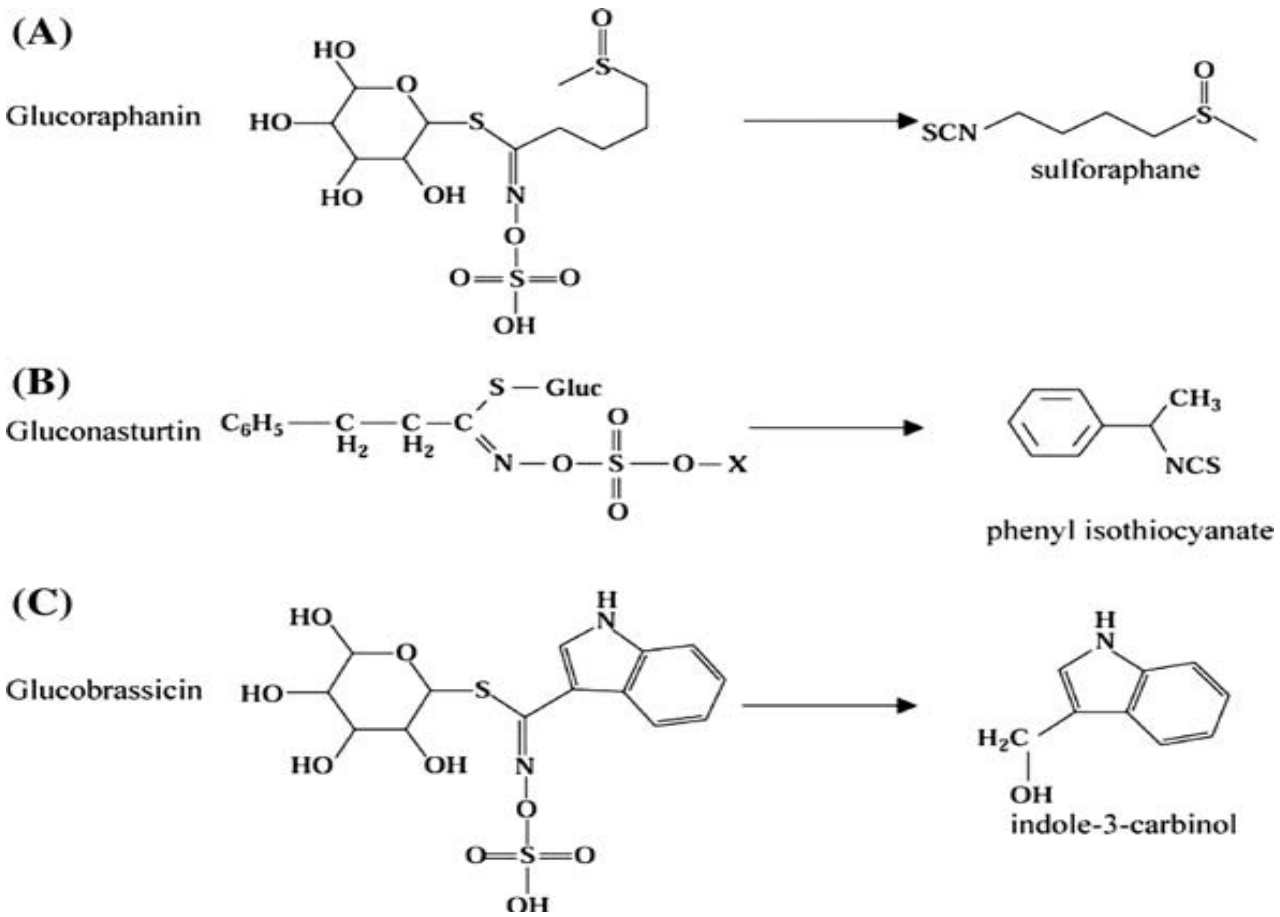

Figure 5. Three types of glucosinolates (Cartea & Velasco 2008)

The above figure illustrates the chain of three types of glucosinolates: alkyl, aromatic and indole along with their respective precursors of biosynthesis as glucoraphanin, gluconasturtin and glucobrassicin. The most important glucosinolates found in Brassica vegetables are methionine-derived glucosinolates (Mithen et al. 2003).

The dominating glucosinolates present in cauliflower are the ones possessing prop-2-enyl-, 3-methylsulphinyl propyl-, 3-indolylmethyl- and 1-methoxy-3-indolylmethyl side chains (Sones et al. 1984). Glucosinolates derived volatile isothiocyanates and nitriles are responsible for the characteristic flavors and aromas of Brassica vegetables (Das 2000; Lewis & Fenwick 1987; MacLeod et al. 1976). The indole glucosinolates such as glucobrassicin and alkenyl glucosinolates such as sinigrin and gluconapin have been responsible for the bitter flavor. In cauliflower, these bitter compounds may suppress taste by the dominating contents of bitter

glucosinolates and glucose (Schonhof et al. 2004). It is this compound that bears indole side-chain and has been associated with cancer protection by the activation of mammalian phase II detoxification enzymes such as glutathione reductase and quinine reductase (Tawfiq et al. 1995). These alleged anti-carcinogenic properties of glucosinolates and their breakdown products are of particular interest in food research. There are some indications that they block tumor initiation by modulating the activities of Phase I and Phase II biotransformation enzymes and suppress tumors by apoptosis (Mithen et al. 2000).

The degradation rate constant of indole-glucosinolates is significantly higher as compared to aliphatic glucosinolates at temperatures below 111°C. Since aliphatic glucosinolates contribute mostly to the characteristic taste of Brassica vegetables, blanching and cooking will have little impact on the taste, while canning is expected to have a large impact on the taste of the vegetables (Oerlemans et al. 2006).

Glucosinolates are expected not to be very susceptible to thermal degradation during blanching. Domestic treatments such as chopping, cooking, steaming and microwaving of the Brassica vegetables have shown to negatively affect the glucosinolates content considerably (Rangkadilok et al. 2002).Cooking will cause more thermal degradation to indole glucosinolates (38%) as compared to aliphatic glucosinolates (8%). Though conventional cooking does not affect the aliphatic glucosinolates significantly; the indole-glucosinolates, however decreased to a higher extent (38%). Canning, the more severe heat treatment, severely affects all glucosinolates (73%), and will therefore have a great adverse impact on the health promoting compounds available in canned Brassica vegetables (Volden et al. 2009b). The concentration of glucosinolates under CA has been equivocal, though has been found to either maintain or increase in broccoli (Rodrigues & Rosa 1999) and cabbage (Verkerk et al. 2001). The glucosinolate content of Brassica vegetables such as broccoli, Brussels sprouts, cauliflower and cabbages was not either decreased or increased significantly when stored at optimum tempretaure of 12-22 ˚C which decreased by 11-27% in 7 days upon storage in a domestic refrigerator (4-8 ˚C). The individual glucosinolates glucoiberin, glucoraphanin and glucoalyssin were higher than that of sinigrin, gluconapin and progoitrin (Song & Thornalley 2007).

The individual glucosinolates gluconapin and glucobrassicin increased with storage time under CA and air-stored treatments but the levels increased earlier in air-stored cauliflower.

Glucobrassicin is prominently a major glucosinolate in cauliflower whose part also depends on genotype (Hodges et al. 2006; Schonhof et al. 2004).

Many contemporary researchers as Rangkadilok et al. (2002); Rodrigues & Rosa (1999); Verkerk et al. (2001) have concluded that the conventional methods of cooking such as boiling, steaming, pressure cooking, deep frying and microwaving drastically reduce the availability of glucosinolates by approximately 30-60% depending upon the type and intensity of the compound. On the other hand, leaching of glucosinolates from broccoli heads, cabbage leaves and Brussels sprouts when cooking in water have been observed to decrease by 40-80% (Rosa & Heaney 1993; Rosa EAS et al. 1997). Similarly, Ciska & Kozłowska (2001) also found a reduction in glucosinolates content after 5 min of cooking (35%) which still reduced to 87% of loss after 30 min in white cabbage. The study by Cartea & Velasco (2008) recommended that microwave cooking is the best alternative for cooking Brassica vegetables as it uses low amount of cooking water thus lowers the activation of myrosinase ultimately getting the minimal loss of glucosinolates. Stir-fry cooking is also the next possibility of cooking with negligible loss of glucosinolates and has been getting one of the popular cooking methods (Song & Thornalley 2007).

3 MATERIALS AND METHODS

3.1 Materials

i. Seeds of Brassica Vegetable Cultivars were obtained from NORGRO AS, Hamar except Nemo which was from EliTop pelliculees, France:
ii. Cabbage cultivars - Bartolo, Castello and Rovite
iii. Cauliflower cultivars - Nemo, Flamenco and Celio(Romanesco) and
iv. Kohlrabi cultivars - Kolibri, Korridor and Kordinal.
v. Sowing trays
vi. Peat and sphagnum moss
vii. Fertilizer fullkjødsel (YARA INTERNATIONAL ASA, Norway)
viii. Sticks and Wonder mesh (Covering Net)
ix. Pesticide (Lentagran-45 WP, Belchim Crop Protection Ltd., Belgium)

3.2 Methods

3.2.1 Seed Sowing

The F1 hybrid seeds were sown in trays (40 cm × 60 cm) inside the Vollebekk greenhouse with 20-22 ˚C day and 18 ˚C night temperature and 16 hours light. Cabbage seeds were sown in May 7th (week 19) while cauliflower and kohlrabi were sown in 14th June 2010 (week 24). The composition of the mixed cultivation medium of peat and sphagnum moss with 86% sphagnum turf H2-H5, 10% sand, 4% granulated clay added with 4.5 kg lime stone per m^3 and 1 kg multimix 13-7-22+Mg containing an acidity of 5.5-6.5.

Figure 6 The sprouted seedlings (cabbage)

3.2.2 Field preparation

The research field of the Norwegian University of Life Sciences (UMB) at Vollebekk, Ås was selected as the field for Master thesis research. The soil type was heavy clay. The dimension of plot for cabbage and cauliflower both was 4.8×1.95 m while that of kohlrabi was 4.0×1.95 m. Altogether 36 randomized plots, for three crops each consisting of 3 cultivars and 4 replications were prepared for transplanting.

3.2.3 Field layout

The field was prepared by ploughing two times and a harrowing and laid out by completely randomized block design (RCBD) and the planting of different cultivars of cauliflower is shown in table 1.

Table 1. Randomized field layout of Cauliflower cultivars

Nemo	Flamenco	Celio
Flamenco	Celio	Nemo
Celio	Flamenco	Nemo
Nemo	Flamenco	Celio

The preceding Table 2 illustrates the randomized block design of planting the selected cultivars Bartolo, Castello and Rovite of cabbage.

Table 2. Randomized field layout for Cabbage cultivars

Bartolo	Rovite	Castello
Castello	Bartolo	Rovite
Rovite	Bartolo	Castello
Bartolo	Castello	Rovite

Similarly, the field layout with complete randomization in planting the selected cultivars of kohlrabi is presented in Table 3.

Table 3. Randomized field layout of kohlrabi cultivars

Kordinal	Kolibri	Korridor
Kolibri	Korridor	Kordinal
Korridor	Kolibri	Kordinal
Korridor	Kordinal	Kolibri

3.2.4 Transplanting

The seedlings were transplanted after 4 weeks of sowing. The cabbage cultivars were transplanted on 2nd of June (week 22) and the cultivars of cauliflower and kohlrabi on 7th of July 2010 (week 27). The planting distance for cauliflower and cabbage both was 40 cm and the row to row distance was 65 cm to ease the movement of the person for intercultural operations and to provide proper aeration and sun light within the plants. The distance between plants in case of kohlrabi was 25 cm and the distance between the rows was the same as in cauliflower and cabbage i.e. 65 cm.

3.3 Intercultural Practices

Intercultural practices such as irrigation, weeding, spraying of pesticides were practiced. The sprinkler system of irrigation was employed as the means of maintaining optimal moisture in the soil to ensure the optimal growth and development of the crops. The field was covered with the wonder mesh (covering net) to protect the crop from the infestation of the insects and birds. Lentagran-45WP (45 gram per 10 liter water) was sprayed on 20th of June 2010 (week 25) to control the weeds in cabbage while cauliflower and kohlrabi was hand weeded. Manual application of the Nitrogen fertilizer 7-8 kg Kalsapeter was applied inside rows preventing it to get inside the growing apex.

3.4 Harvesting

Different cultivars of crops were harvested respective of their planting time and gaining the harvesting maturity of the crop cultivar (table 5). Among cauliflower cultivars, Flamenco was the shortest cultivar taking 8 weeks after transplanting and was harvested on 1st September (week 35), whereas Nemo and Celio (Romanesco) were harvested 10th September (week 36) and 15th September (week 37) with a growing period of 9 and 10 weeks respectively.

Kohlrabi cultivars attained synchronized harvesting maturity after 6 weeks of transplanting where Korridor and Kordinal were harvested in 13th August 2010 (week 33) and Kolibri was harvested at 19th of August (week 33). Similarly, the cabbage cultivars took the longest period (11 weeks) as compared to cauliflower and kohlrabi and were harvested on 16th of August (week 33).

Figure 7 Harvesting (kohlrabi)

3.5 Experimental Setup

The preceding Table 4 illustrates the different treatments performed with their respective conditions needed to be maintained regarding the day and night temperature. Treatment 1 was the control which was directly deep freezed after taking the weight of the produce at harvest. The corresponding figures 8, 9 and 10 show the state of storage in three treatments 0 ^{o}C, 5 ^{o}C and Ice in cauliflower cultivar Celio.

Table 4. The set-up of the experiment with the different treatments and conditions

Experiments	Treatment 1 (Control) At Harvest	Treatment 2 0 °C	Treatment 3 5 °C	Treatment 4 Ice
Conditions	Direct preservation at -40 °C	Stored at day & Night temperature at 0 °C	Stored at day & Night temperature at 5 °C	Stored in a box and covered with ice leaving the top

Figure 8 Storage of cauliflower cv. Celio at 0 ˚C

Figure 9 Storage of cauliflower type Romanesco at 5 oC

Figure 10 Storage of Celio in ice

3.6 Storage Conditions

The selected cultivars of the Brassica crops grown were harvested after 6 weeks (kohlrabi), 8-10 weeks (cauliflower) and 11 weeks (cabbage) after transplanting. Then each head (tightly compacted leaves) of cabbage, curd of cauliflower or bulb (swollen stem) of kohlrabi was weighed with a digital weighing machine (figure 8) and recorded. The fruit head/curd/bulb was plastic wrapped before storage in 0 ^{o}C and 5 ^{o}C and placed in a basket in a room maintained at 0 ^{o}C and 5 ^{o}C respectively. While the produce were placed inside the styrofoam shipping (insulating) boxes filled with ice slightly exposing the above part to the atmosphere as shown in figure 9 and was also placed in the same room maintained at 0 ^{o}C. The storage duration for every crop cultivar and treatment was about 6-7 weeks. During storage, more ice was added 2-3 times as it melted due to the ongoing metabolism of the crop produce and the temperature loss from the room. The relative humidity of the room was maintained above 95%.

Figure 11 Weighing at harvest (kohlrabi)

Figure 12 Storage in ice (kohlrabi)

3.7 Sample preparation

The samples stored for quality analysis were obtained by cutting in halves vertically as in figure 13 and taking about 1/3rd cross section of one half covering the outer tight leaves to the inner core removing the stalk from 4 replicated heads of each treatment. In case of cauliflower, the curd was vertically cut in two halves and the flowers were detached from one quarter of a half rejecting the main stalk. Similarly, the bulb of the kohlrabi was cut in half and in quarters. One quarter from the base of the stalk covering from the inner core to the outer skin was taken. The sample was mixed taking a cross-section from 3 replication of each cultivar in each treatment representing each head/curd/bulb into account. The samples were then cut in small pieces (figure 14) and a part of the sample thus prepared was immersed in liquefied Nitrogen to reduce the moisture from the samples (figure 15) and were preserved at -40 ˚C in deep freezing condition at Senter for Klimaregulert Planteforskning (SKP). The thus prepared samples were then analyzed to examine anti-oxidant activity, total phenol, L-ascorbic acid and dry matter (DM) in the fruit laboratory (SKP).

Figure 13 Vertical cross-section of cabbage (Rovite)

Figure 14 Sample preparation in cauliflower cv. Celio

Figure 15 Separating after the immersion in liquified Nitrogen

Table 5. growing duration and storage periods

Crops	Cultivars	Growing (weeks)	Storage (weeks)
Cauliflower	Flamenco	8	6
	Nemo	9	6
	Celio	10	6
Cabbaage	Bartolo	11	7
	Castello	11	7
	Rovite	11	7
Kohlrabi	Kordinal	6	7
	Korridor	6	7
	Kolibri	6	7

3.8 Analysis of Anti-oxidant activity (FRAP)

3.8.1 Materials

Samples: Cauliflower, Cabbage, Kohlrabi

Hand blender, Weighing machine, Oxalic acid i.e. 10 mM HCL (*Merck KGaA*, *Darmstadt*, *Germany)*, Liquid Nitrogen, Vortex, Water bath

Konelab 30i (Thermo Electron Corp. Vantaa, Finland)

3.8.2 Method

The frozen samples were homogenised using immersion hand blender (BRAUN-4185, Spain). 3 g of the weighed sample was taken in a bottle of 50 ml. 30 ml of acidified (10mM HCL) methanol was added to the sample. The air in the sample was removed by the Nitrogen vapour. It was then shaken on vortex (GENIE-2-T, SI-T256; Scientific Industries Inc., USA) for about 30 seconds to homogenise the solution and sonicated on ultrasonic bath (RK 100/42138, Bandelin Electronic KG, Germany) at 0 °C for 15 minutes. Finally, 2ml of the sample taken in a micro tube (SARSTEDT, Germany) was placed in a centrifuge (R134A, Eppendorf AG, Hamburg, Germany) at 103 g for 2 min at 4 °C and transferred to Konelab 30i (Thermo Electron Corp. Vantaa, Finland) for the analysis.

3.8.3 Principle

The Ferric Reducing Ability of Plasma (FRAP) assay was used to measure the concentration of total antioxidants. The method is based on the colour changes when the TPTZ-Fe^{3+} (2, 4, 6-tri-pyridyl-s-trizine) complex is reduced to the TPTZ-Fe^{2+} form at low pH in the process of reduction. Under this reduction, an intense blue colour with the absorption maximum at 593 nm develops (Benzie & Strain 1996b). FRAP values are obtained by comparing this absorption change in test reaction as compared to the ferrous ion in known concentration (Benzie & Strain

1996a). The measurements were performed at 600 nm. An aqueous solution of 500 µM $FeSO_4$ x $7H_2O$ was used for calibration of the Konelab 30i (Thermo Electron Corp. Vantaa, Finland). The antioxidant activity of a crop is expressed as *mmol/100g FW*.

3.9 Analysis of L-ascorbic acid

3.9.1 Materials

Samples: Cauliflower, Cabbage, Kohlrabi

Homogenizer, Oxalic acid i.e. 10 mM HCL *(Merck KGaA, Darmstadt, Germany)*, Beaker, Filter, Sep-pak column, Syringe, Millipore filter, vials

High Performance Liquid Chromatography i.e. HPLC unit (Agilent Technologies, 1100 Series, USA)

3.9.2 Method

The preserved samples after different storage conditions were crushed with a knife and 50g of the sample was taken and 1% oxalic acid dehydrate was added to make 150g total sample volume. It was then grinded and homogenized for one minute and the homogenate was filtered through Φ125mm filter paper (Whatman, USA). This sample, filtered through an activated (by 5ml methanol and washed with 5ml de-ionized water) sep-pak C-18 column (Waters, Ireland), and was filtered through a 0.45µm Millipore filter (Millex-HA, Carrigtwohill Co. Ireland) in 1.5 ml vials (VWR International). The first 2 ml of the analytical sample was discarded and transferred to HPLC (Agilent Technologies, 1100 Series, USA) for the L-ascorbic acid analysis.

3.9.3 Principle

L-ascorbic acid was analyzed with the chromatographic process using High Performance Liquid Chromatography (HPLC). The process is defined as separation technique involving mass-transfer between mobile and stationary phase. HPLC utilizes a liquid mobile phase to separate the components of a mixture. The stationary phase can be a liquid or a solid phase.

It uses a flow of 1 ml/minute and temperature 25 ^{o}C. There are two 5µ columns (ZORBAX SB-C18, Agilent Technology, USA) of which the retention time is slightly different (new column - about 3.0 min and old column - about 3.5 min.). The UV-detector detects L-ascorbic acid at absorbance 254 nm. The time required is about 5 minute per analyses of sample injection volume 5µl. It consists of mobile phase; 0.05 M KH_2PO_4 (Chebrolu et al. 2012). The value is expressed as *mg L-asc/100g FW*.

3.10 Analysis of Total Phenols

3.10.1 Materials

Samples: cauliflower, cabbage and kohlrabi

Methanol, Vortex, Ultrasonic bath, Microtube, Centrifuge, Folin-Ciocalteu's phenol reagent (FCR)

Konelab 30i (Thermo Electron Corp. Vantaa, Finland)

3.10.2 Method

The thus prepared sample of about 3g was taken and 30 ml methanol was added to it which was then shaken with the vortex (GENIE-2-T, SI-T256; Scientific Industries Inc, USA) for 30 seconds. It was placed in ultrasonic bath (RK 100/42138, Bandelin Electronic KG, Germany) at 0 ^{0}C for 15 minutes. It was then filled in a 2 ml micro tube (SARSTEDT, Germany) and was placed in a centrifuge (R134A, Eppendorf AG, Hamburg, Germany) for 3 minutes at 103 g at 4 ^{0}C to precipitate the sample constituents. Now, the sample was placed on Konelab 30i (Thermo Electron Corp. Vantaa, Finland) for total phenol analysis.

3.10.3 Principle

This is based on the reduction of Folin-Ciocalteu's phenol reagent (FCR), a mixture of tungsten and molybdenum oxides, resulting in blue colored product with absorbance maximum at 765 nm.

The 20 µl sample together with the standard solutions (100 µl FCR) were pipetted directly into the cyvettes and mixed and incubated at 37 ^{o}C for 60 s. It was then pipetted through Sodium carbonate solution of 80 µl 7.5% (w/v), mixed and incubated at 37 ^{o} C for 15 minutes when there was no more significant increase in absorbance. The measurement of absorbance was carried out at 765 nm. This intensity of absorption is equivalent to the sum of the individual attribute of the different types of phenols present in the mixture (Singleton et al. 1999; Slinkard & Singleton 1977). The total phenol content is expressed as mg gallic equivalents (GAE)/100g FW.

3.11 Analysis of Dry Matter (DM)

3.11.1 Materials

Samples: cabbage, cauliflower and kohlrabi

Oven, Vacuum desiccator, Digital Weighing balance

3.11.2 Method

The dry matter of 6g of the homogenized samples for analysis of antioxidant activity was oven dried at 104˚C (TS-8136, Termaks, Norway) for 24 hours. It was taken out and placed in vacuum desiccators (Glaswerk Wertheim, Germany) for 15 minutes and weighed with the digital weighing balance (PG 503-SDR, Meltler Toledo, Switzerland).

3.11.3 Principle

Dry matter (dry weight of all its solids excluding water) analysis is a commonly used method of determining the total major and trace elements contained in the plant tissue when it is completely dried. It is expressed as a percentage.

3.12 Data Analysis

The results of the experiment were expressed as mean ± standard deviation of the four replicates. Data were analyzed by analysis of variance using Minitab statistical software version 16. Analysis of mean values and test of significance was performed by two way ANOVA technique and differences among means were tested by Turkey's Least Significant Difference (LSD) at P = 0.05.

Statistical model for the analysis:

$Yij= \mu+Ti +\beta j+\varepsilon ij$

where

i= no of treatment, 1,2,3 & 4

j= no. of blocks, 1,2 & 3

yij= onservation for the i^{th} treatment in j^{th} block

$\beta j= j^{th}$ block effect

μ= true mean effect

Ti= true effect of treatment i

$\varepsilon ij=$ error effect of the j^{th} unit subjected to i^{th} treatment

4 RESULT

This section provides an analysis of effect of temperature on different phytochemical parameters (dry matter, antioxidant activity, total phenol and L-ascorbic acid contents) of cauliflower, cabbage and kohlrabi. Analyses (comparison) were done between treatments and cultivars of each crop respectively.

4.1 Cauliflower

All three cultivars of cauliflower responded differently to different treatments. Similarly, the responses of phytochemical parameters to the treatments also varied.

4.1.1 Dry matter

4.1.1.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on dry matter content of cauliflower cultivars

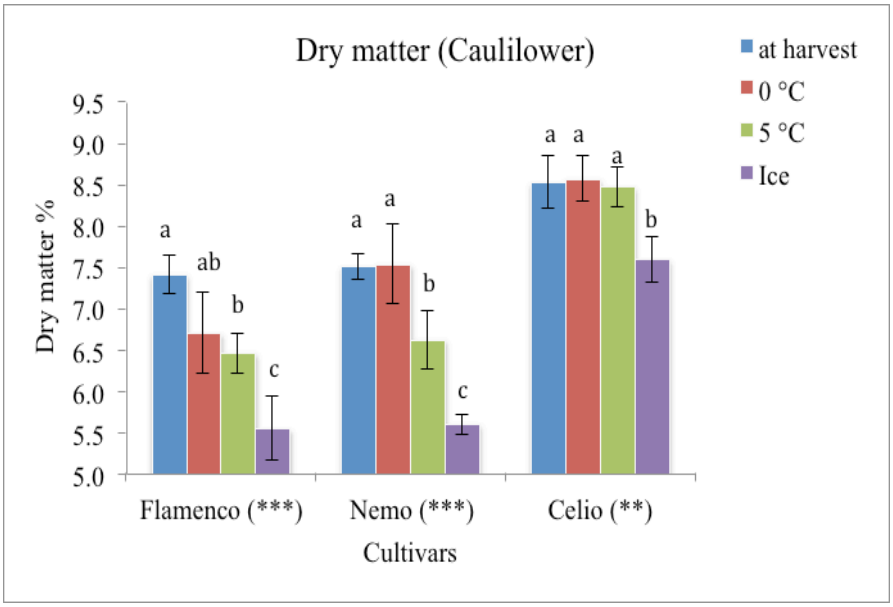

Figure 16 Effect of temperature (0 °C, 5 °C and ice) on dry matter contents of Cauliflower Cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter are not significantly different at p = < 0.05.

** Significance at $p \leq 0.01$

*** Significance at $p \leq 0.001$.

It was found that, in cultivar Flamenco, dry matter content was significantly reduced at 5 °C and ice storage than at harvest condition (figure16, table 6), the more pronounced loss was in ice (≥ 25.23 %) followed by 5 °C (≥ 9.5 %) treatment. However, loss of dry matter at 0 °C was not comparable with at harvest and 5 °C ($p < 0.05$). Similarly, in Nemo, it considerably decreased in ice (≥ 25.45%) and 5 °C (≥ 11.7 %) than at harvest and 0 °C treatments. At the same time, the dry matter was significantly lower in ice than at 5 °C. Result showed that the dry matter content, in Celio was remarkably declined in ice than other treatments but the loss was not significant among three treatments.

4.1.1.2 Response of Cauliflower cultivars on dry matter content in different temperature conditions

Dry matter content of cauliflower cultivars varied depending upon treatments. Figure 17 and table 7 depict that cultivar Celio demonstrated significantly higher dry matter content compared to Flamenco and Nemo ($P \leq 0.05$) at all treatments. But there was no significant difference between Flamenco and Nemo during these conditions.

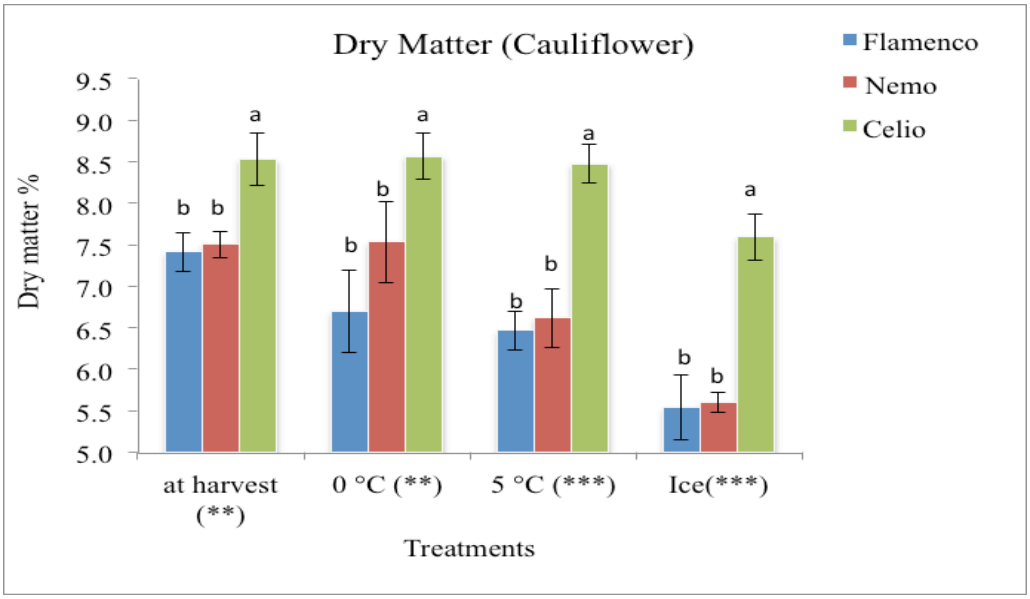

Figure 17 Response of Cauliflower cultivars on dry matter content at different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at $p = < 0.05$

** Significance at $p \leq 0.01$

*** Significance at $p \leq 0.001$.

4.1.2 Antioxidant activity (FRAP)

Antioxidant activity was found to be varying in different cauliflower cultivars depending upon the cultivar and treatments.

4.1.2.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on antioxidant activity (FRAP) content of cauliflower cultivars

Data revealed that the antioxidant activity in cultivar Flamenco and Celio significantly increased at 0 °C, 5 °C and ice treatments than at harvest condition ($P \leq 0.05$) though significant difference was not observed among 0 °C, 5 °C and ice treatments. Similarly, in Nemo, it was significantly higher at 0 °C and 5 °C than at harvest and in ice treatments. However it did not significantly vary between 0 °C and 5 °C, and at harvest and ice (figure 18 table 6).

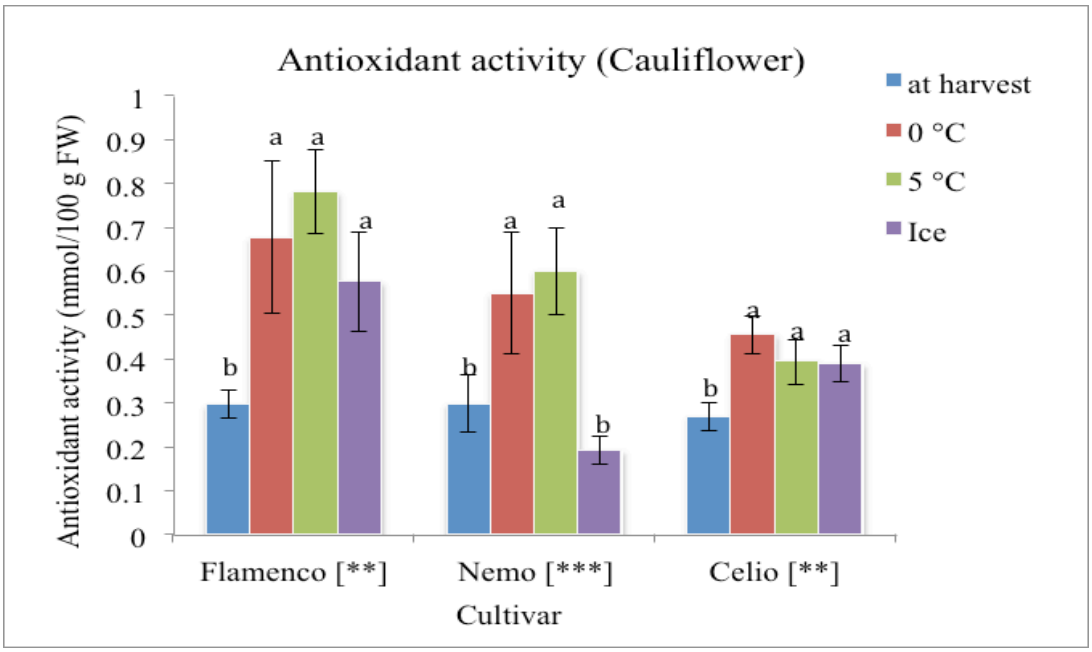

Figure 18 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on antioxidant activity of cauliflower cultivars Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at $p = < 0.05$.

** Significance at $p \leq 0.01$

*** Significance at $p \leq 0.001$.

Response of Cauliflower cultivars on antioxidant activity (FRAP) contents in different temperature conditions

Antioxidant activity among cultivar Flamenco, Nemo and Celio did not vary significantly at harvest and 0 °C treatments (P ≤ 0.05). In 5 °C treatment, it was significantly higher in Flamenco (0.78 mmol/100g FW) followed by Nemo (0.60 mmol/100 g FW) and lowest in Celio (0.39 mmol/100g FW). Similarly, Flamenco demonstrated significantly highest antioxidant activity in ice accompanied by Celio and Nemo (Fig 4, table 2).

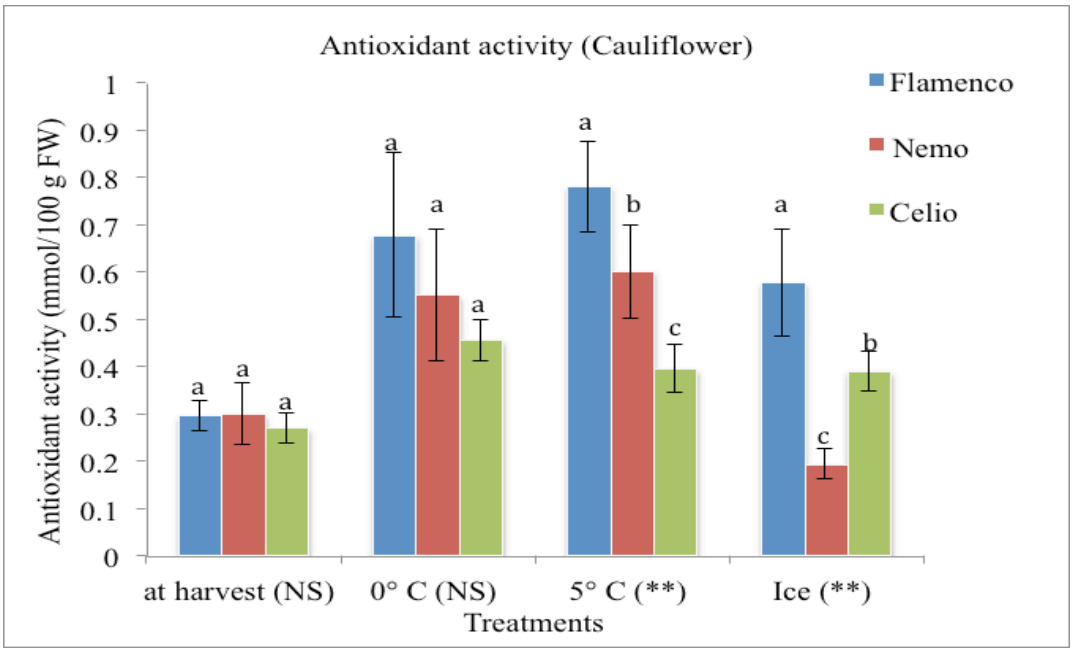

Figure 19 Response of Cauliflower cultivars on antioxidant activity at different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean Bars with the same letter within the group are not significantly different at $p = < 0.05$

NS non-significance at p (≤ 0.05)

** Significance at $p \leq 0.01$

4.1.3 Total Phenol

4.1.3.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on total phenol contents of cauliflower cultivars

It was demonstrated in present study that the total phenol content in three cultivars was statistically different at different storage conditions. In Flamenco, it drastically increased at all three 0 °C, 5°C and ice storage conditions than at harvest ($P \leq 0.05$). Similarly, significantly higher total phenol content was recorded on 5 °C (0.78 mg GAE/100g FW) storage condition than in ice. But it was not statistical difference between on 0 °C and 5 °C and 0 °C and ice (figure 20, table 6).

Likewise, in Nemo, total phenol content noticeably increased at 0 °C and 5 °C than at harvest and ice treatments while remarkably lower value was recorded in ice (39.14 mg GAE/100g FW) than the other treatments. However, it did not vary during 0 °C and 5 °C storage treatments.

In Celio, total phenol content, significantly increased at three storage treatments than at harvest condition and at the same time, significant difference was recorded between 0 °C and ice. However, total phenol content at 5 °C did not vary with 0 °C and ice ($P \leq 0.05$)

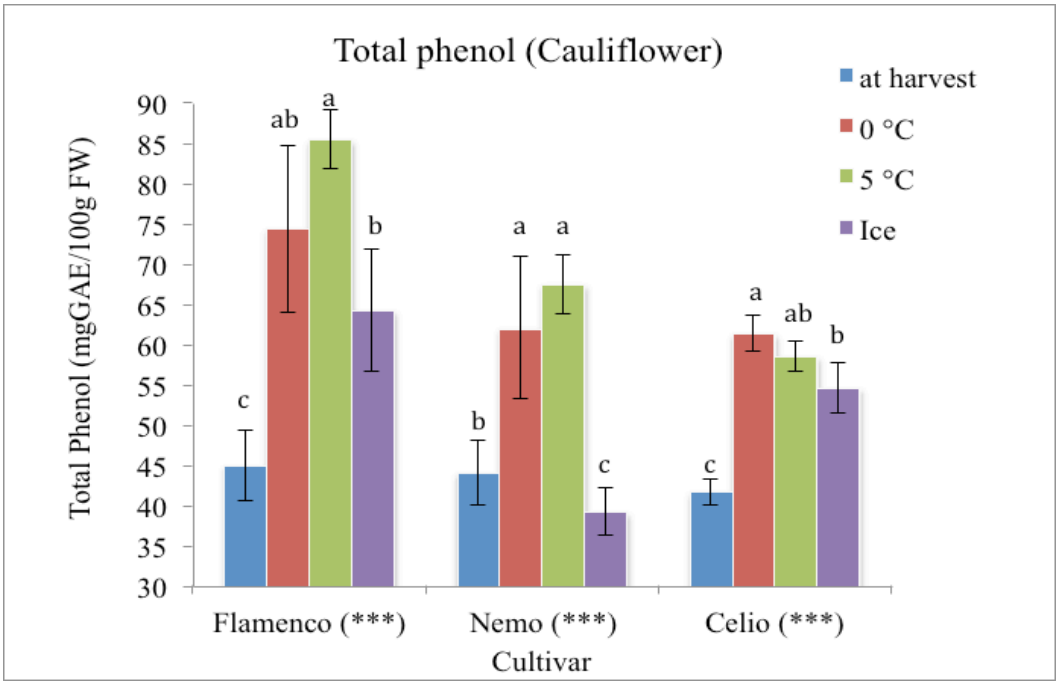

Figure 20 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on total phenol contents of different cauliflower cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at p = < 0.05.

*** Significance at $p \leq 0.001$.

4.1.3.2 Response of Cauliflower cultivars on total phenol contents in different temperature conditions

Total phenol content among three cultivars at harvest and 0 °C treatments was not statistically different (P ≤ 0.05). At 5 °C, Flamenco had the highest (85.39 mg GAE/100g FW) total phenol content, medium (67.46 mg GAE/100g FW) in Nemo and lowest (58.47 mg GAE/100g) in Celio (figure 21, table 7). Similarly, in ice, total phenol content was lower in Nemo than in Flamenco and Celio but it did not vary among Flamenco and Celio.

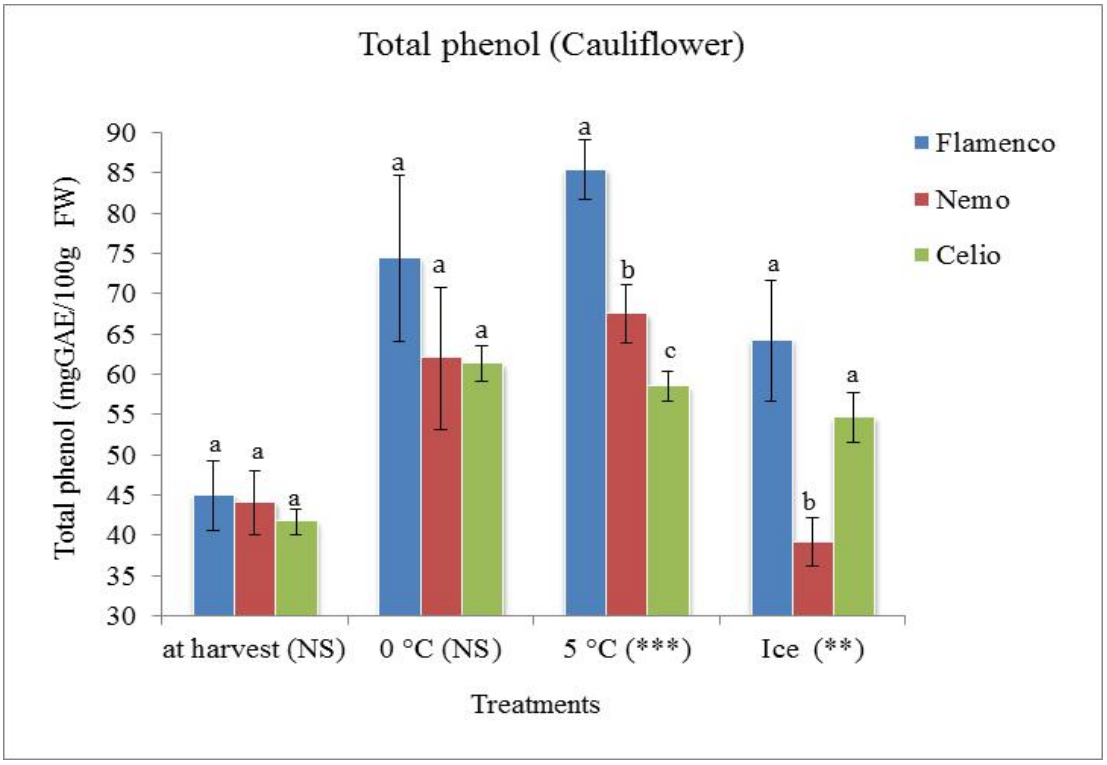

Figure 21 Response of cauliflower cultivars on total phenol contents in different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at p = < 0.05.

NS non- Significant at p (≤ 0.05)

** Significant at $p \leq 0.01$

*** Significant at $p \leq 0.001$.

4.1.4 L- ascorbic acid

4.1.4.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on L-ascorbic acid content of cauliflower

L-ascorbic acid content in cultivar Flamenco considerably increased in ice, 0 °C and 5 °C than at harvest (LSD 5%). The highest (70.33 mg L-asc /100g FW) L-ascorbic acid content was recorded in treatment ice and least (55.64 mg L-ascorbic acid /100g FW) at harvest (figure 22, table 6).

In cultivar Nemo, L-ascorbic acid content significantly increased at 0 °C and ice storage than at harvest conditions at ($P \leq 0.05$) but it did not vary between at harvest and 5 °C. In cultivar Celio, L-ascorbic content considerably declined at 5 °C and in ice. But it did not vary between at harvest and 0 °C and ice and 5 °C treatments.

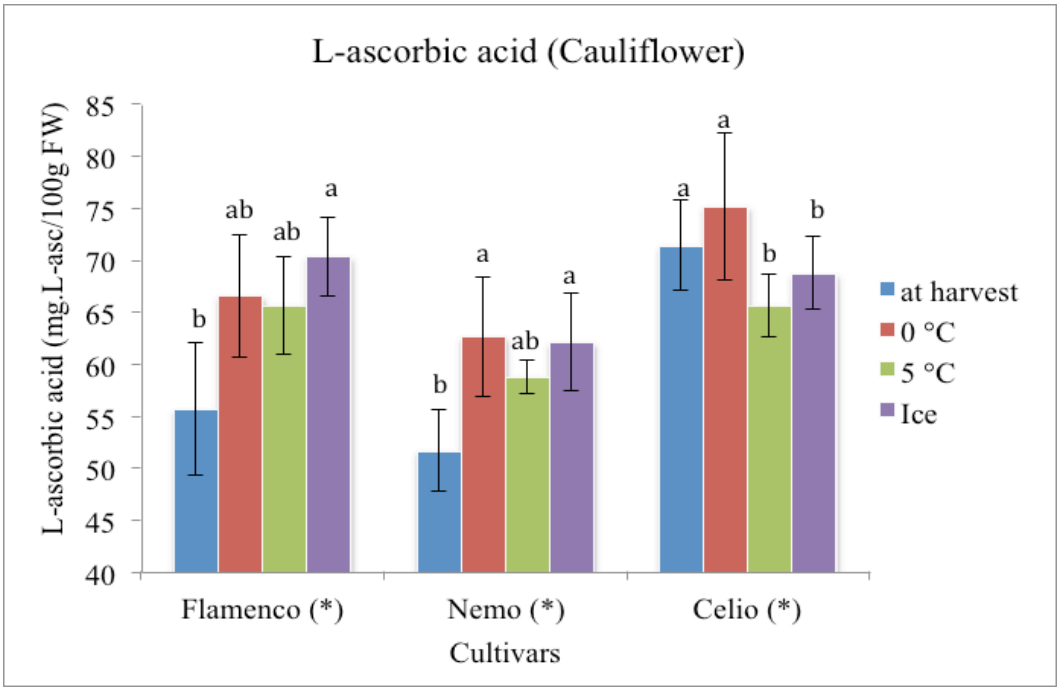

Figure 22 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on L-ascorbic acid content in cauliflower cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at p = < 0.05.

* Significant at $p \leq 0.05$.

4.1.4.2 Response of Cauliflower cultivars on L-ascorbic acid content in different temperature conditions

It was discovered that L-ascorbic acid content in three cultivars of cauliflower was enhanced at storage treatments. At harvest condition, cultivar Celio contained the highest (71.37 mg L-asc /100g FW) amount of L-ascorbic acid content as compared to Flamenco and Nemo (figure 23 table 7). However, there was no significant difference between Flamenco and Nemo ($P \leq 0.05$). In 0 °C storage, Celio revealed the increased (75.18 mg L-asc /100g FW) L-ascorbic content as compared with Nemo (62.64 mg L-asc /100g FW). However, cultivar Flamenco did not vary with Nemo and Celio (figure 23, table 7).

At 5 °C, L-ascorbic acid content in cultivar Nemo was found to be significantly lower (58.75 mg L-asc /100g FW) compared to cultivar Flamenco and Celio at ($P \leq 0.05$). In ice, Flamenco contained significantly highest (70.33 mg L-asc /100g FW) amount of L-ascorbic acid content compared to Nemo though it was not significantly different between Flamenco and Celio.

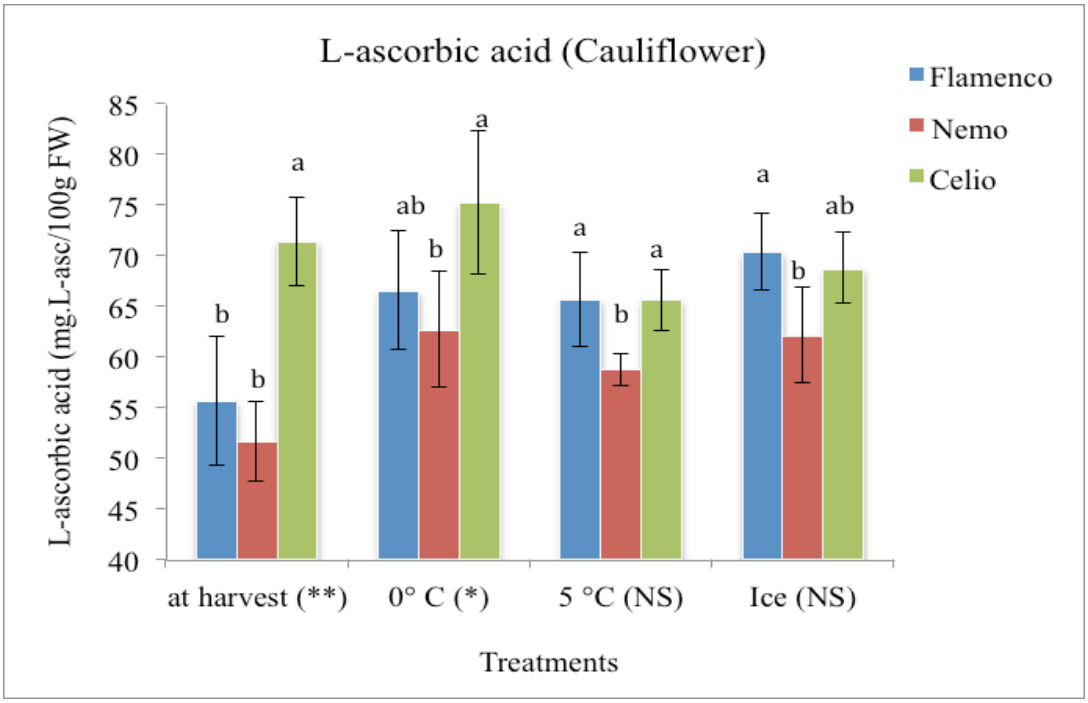

Figure 23 Response of Cauliflower cultivars on L-ascorbic acid content different temperature conditions. Data are the mean values of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at p = < 0.05.

NS non- significant at $p \leq 0.05$

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

4.2 Cabbage

4.2.1 Dry matter

4.2.1.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on dry matter contents of Cabbage cultivars

Dry matter content in cultivar Bartolo and Rovite did not vary significantly at harvest and other treatments ($P \leq 0.05$). In cultivar Castello, dry matter content at 5 °C was less than at harvest (figure 24, table 8). Similarly, there was no difference between at harvest, 0 °C and ice.

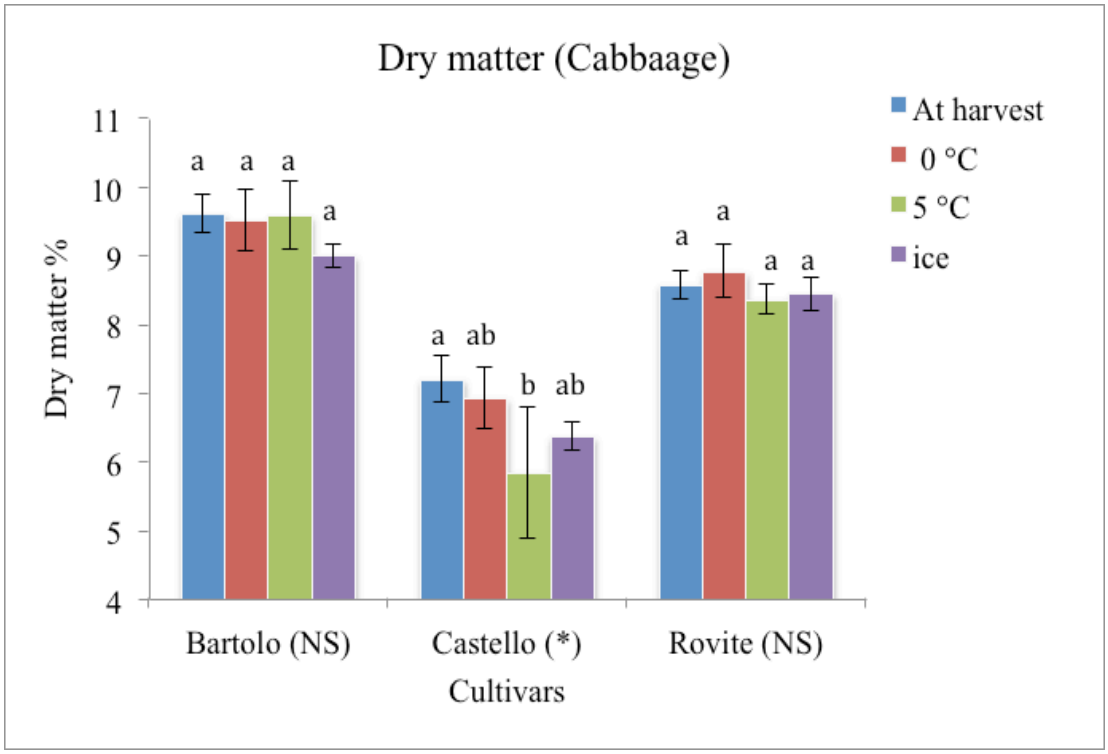

Figure 24 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on dry matter contents of cabbage cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at p = < 0.05.

NS non- significant at $p \leq 0.05$

* Significant at $p \leq 0.05$

4.2.1.2 Response of Cabbage cultivars on dry matter contents in different temperature conditions

In the present study, dry matter content between the cultivars of cabbage was found to be different at treatments 0 °C, 5 °C and in ice. At harvest, highest dry matter content was in Bartolo (9.61%), the lowest in Castello (7.20 %) and medium in Rovite (8.57%) at ($P \leq 0.05$).

Similarly, cultivar Castello (6.93%) revealed lower dry matter content than the other two cultivars in treatment 0 °C, 5 °C and in ice but there was no difference between Bartolo and Rovite (figure 25, table 8) at the same time.

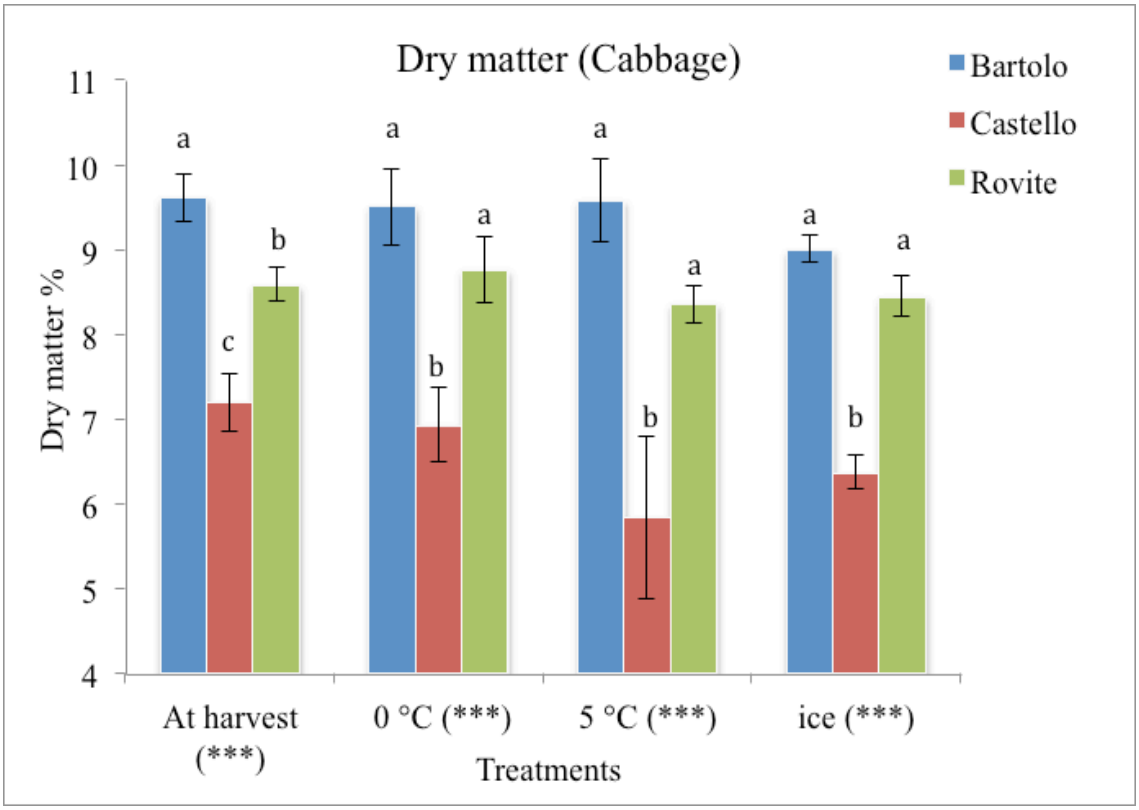

Figure 25 Responses of Cabbage cultivars on dry matter contents in different treatments. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at $p = 0.05$

*** Significant at $p \leq 0.001$

4.2.2 Antioxidant activity

4.2.2.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) to antioxidant activity of Cabbage cultivars

Antioxidant activity in cultivar Bartolo and Rovite did not vary significantly at four (at harvest, 0 °C, 5 °C and ice) treatments observed at ($P \leq 0.05$).

In Castello, antioxidant activity was lower (0.22 mmol/100g FW) at harvest condition as compared to 0 °C, 5 °C and ice. But it did not vary among 0 °C, 5 °C and ice treatments at ($P \leq 0.05$) (figure 26 table 8).

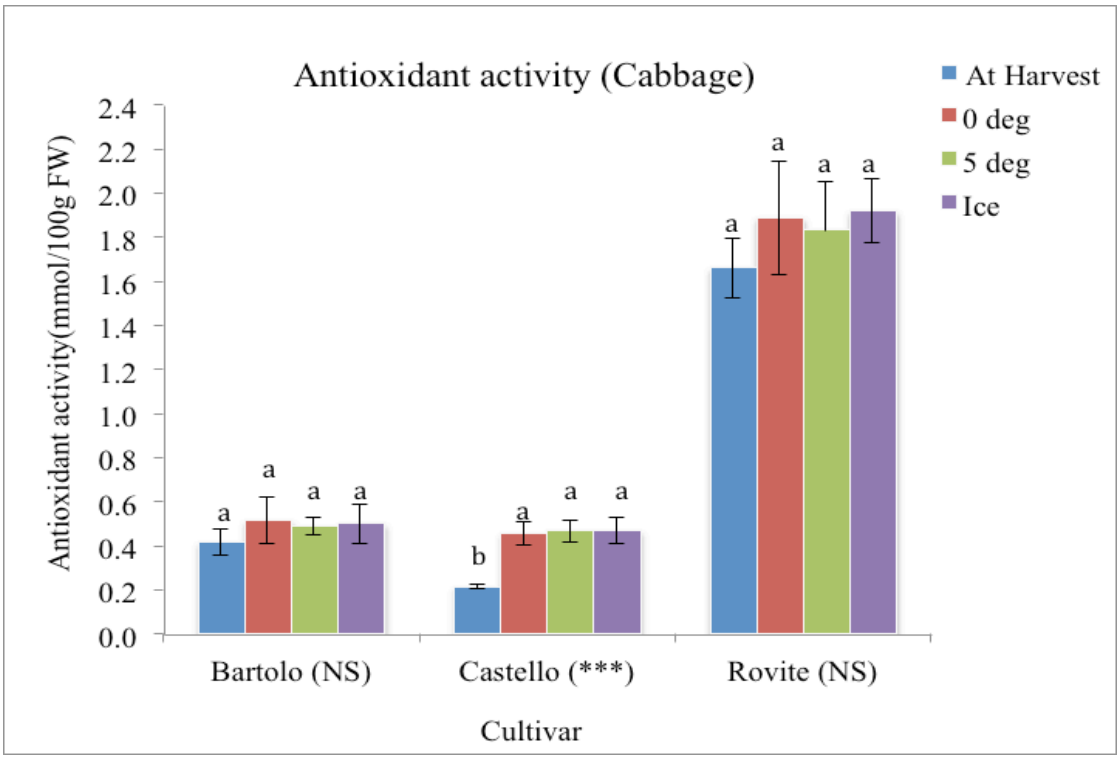

Figure 26 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on antioxidant activity of cabbage cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with the same letter within the group are not significantly different at $p = 0.05$

NS non-significant at $p \leq 0.05$

*** Significant at $p \leq 0.001$

4.2.2.2 Response of Cabbage cultivars to antioxidant activity in different temperature conditions

Antioxidant activity at harvest condition among Bartolo, Castello and Rovite varied significantly ($P \leq 0.05$). It was drastically higher in Rovite (1.66 mmol/100g FW) medium in Bartolo (0.42mmol/100g FW) and lowest in Castello (0.22 mmol/100g FW) (figure 27 table 9).

In ice, 0 °C, and 5 °C storage conditions; the content of antioxidant activity was dramatically higher in Rovite as compared with Bartolo and Castello. However, it was not significant between Bartolo and Castello except at harvest where there was significant difference between two cultivars.

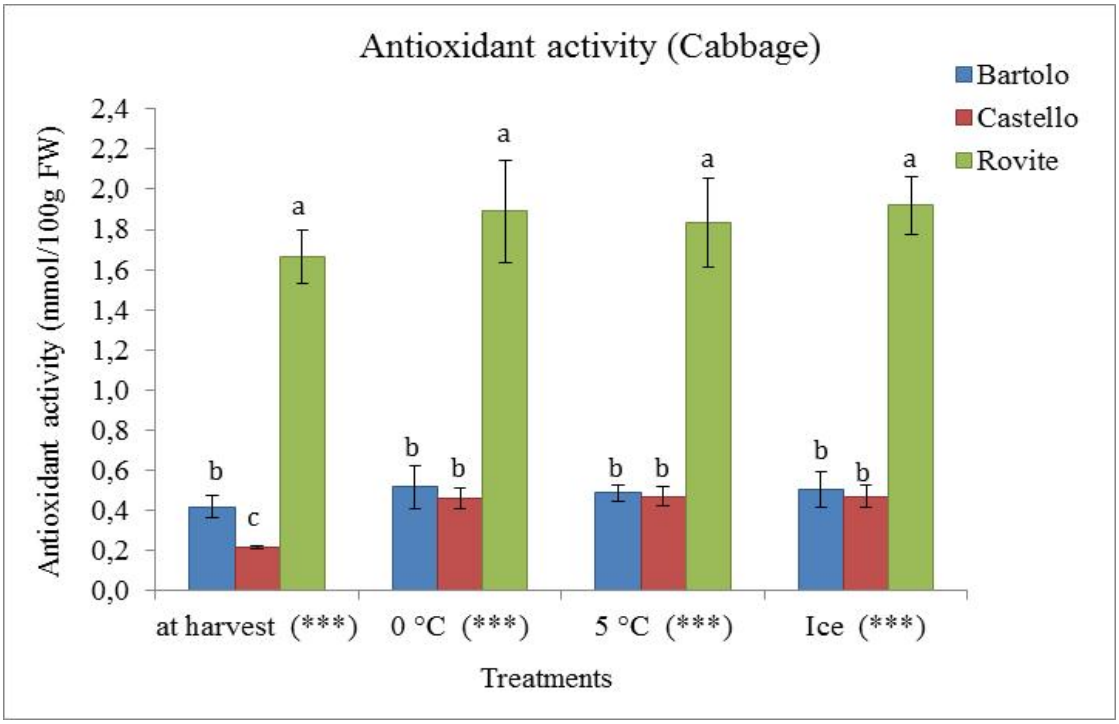

Figure 27 Response of Cabbage cultivars on antioxidant activity in different treatments. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within the group are not significantly different at $p = 0.05$

*** Significant at $p \leq 0.001$

4.2.3 Total Phenol

Total phenol content differs among cultivar and treatments. The data and figures below will explain the specific trends of total phenol contents.

4.2.3.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on total phenol contents of Cabbage cultivars

Total phenol content in cultivar Bartolo and Rovite had no significant variation among at harvest and other three (0 °C, 5 °C and ice) storage conditions ($P \leq 0.05$). In case of Castello, it increased during three (0 °C, 5 °C and ice) storage treatments than at harvest. However, it did not vary among 0 °C, 5 °C and ice (figure 28, table 8).

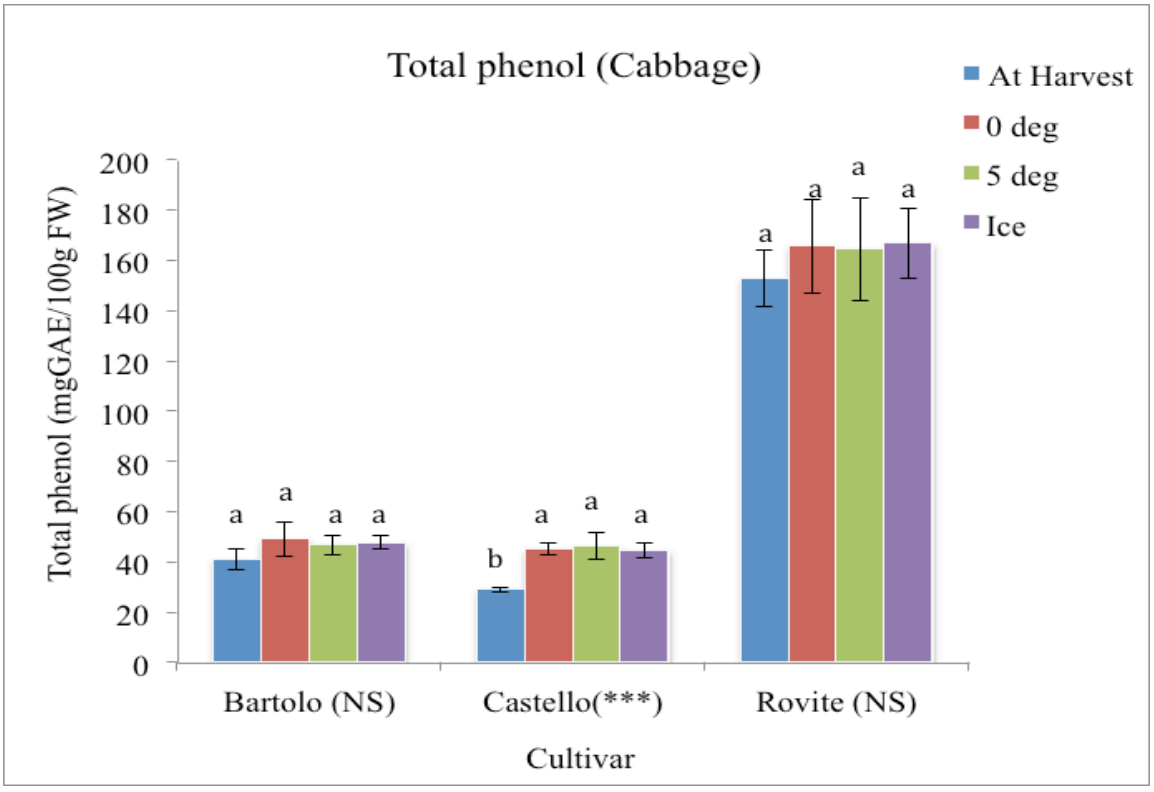

Figure 28 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on total phenol contents of cabbage cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within the group are not significantly different at $p = 0.05$.

NS non-significant at $p \leq 0.05$

*** Significant at $p \leq 0.001$

4.2.3.2 Response of Cabbage cultivars on total phenol content in different temperature conditions

Result demonstrated that the total phenol content in Rovite was dramatically higher (153.05 mg GAE/100 FW) than other two cultivars, the medium in Bartolo (41.16 mg GAE/100 FW) and Castello being the lowest (29.12 mg GAE/100) at 0 °C, 5 °C and in ice ($P \leq 0.05$). In 0 °C, 5 °C and in ice storage, Rovite expressed abundancy of total phenol (165.88 mg GAE/100 FW) content compared to Bartolo and Castello. However, this did not differ significantly between Bartolo and Castello (figure29, table 9).

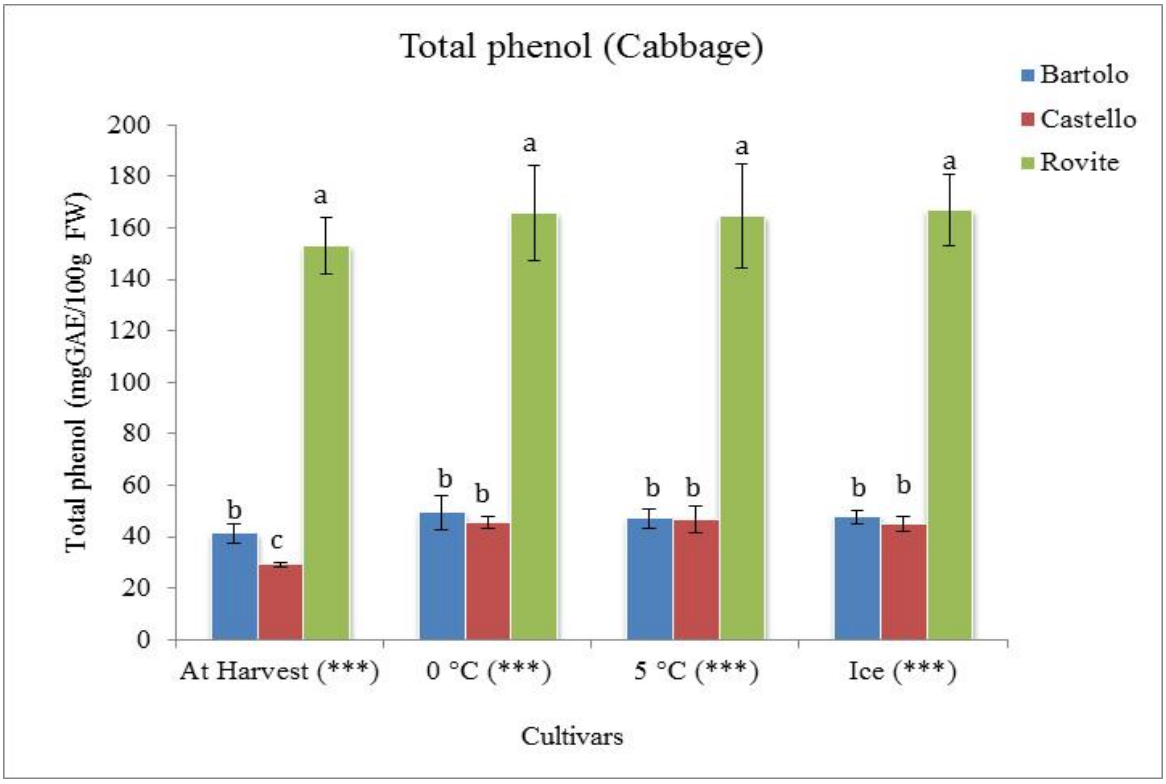

Figure 29 Response of Cabbage cultivars on total phenol contents in different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same latter within the group are not significantly different at p= 0.05.

*** Significant at $p \leq 0.001$

4.2.4 L-ascorbic acid

4.2.4.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on L-ascorbic acid content of Cabbage cultivars

L-ascorbic acid content in Bartolo and Castello during four treatments did not vary ($P \leq 0.05$). Whereas, it increased with the storage in ice than at harvest and 0 °C treatments in Rovite (figure30, table 8).

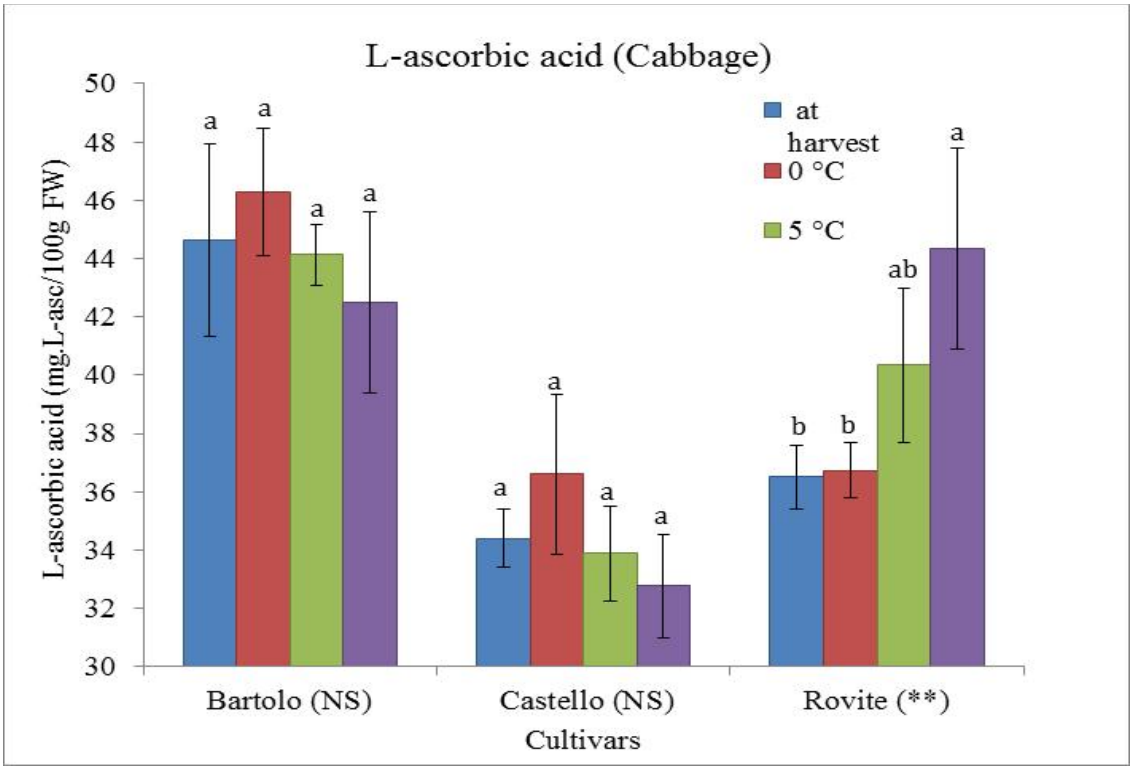

Figure 30 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on L-ascorbic acid contents of cabbage cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at p = 0.05.

NS non-significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

4.2.4.2 Response of Cabbage cultivars on L-ascorbic acid contents in different temperature conditions

At harvest and 0 °C, L-ascorbic acid content was higher in Bartolo compared to cultivars Castello and Rovite at ($P \leq 0.05$). It did not vary significantly between Castello and Rovite (figure 31, table 10). Similarly, in treatment 5 °C, L-ascorbic acid content among three cultivars varied significantly. The highest L-ascorbic acid content was recorded in Bartolo (44.13 mg L-asc/100g FW) followed by Rovite (40.34 mg L-asc/100g FW) then by Castello (33.88 mg L-asc/100g FW). In case of ice, the content was lower in Castello (32.77 mg L-asc/100g) compared with Bartolo and Castello but difference was not recorded between Rovite and Bartolo.

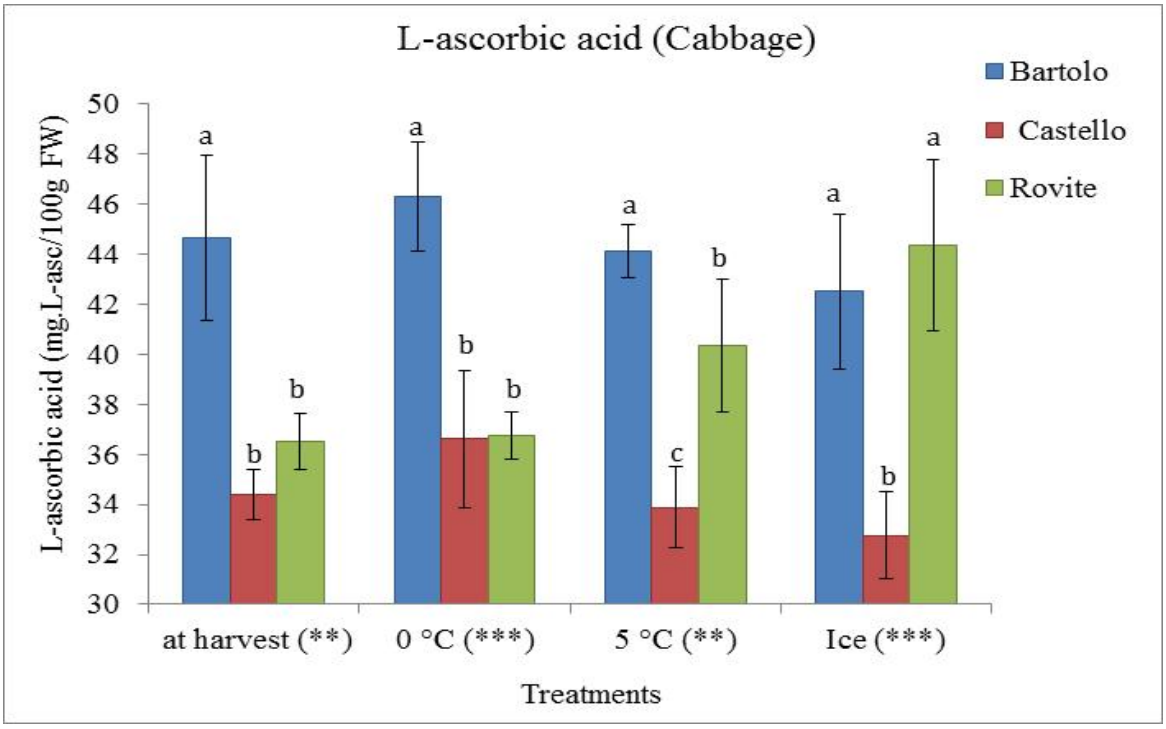

Figure 31 Response of Cabbage cultivars on L-ascorbic acid content in different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at $p = 0.05$.

*** Significant at $p \leq 0.001$

4.3 Kohlrabi

4.3.1 Dry matter

4.3.1.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on dry matter contents of kohlrabi cultivars

In Kohlrabi cultivar Kordinal, dry matter content did not vary among treatments at ($p < 0.05$) In Kordinal, dry matter content revealed higher mean standard deviation than in other treatments (figure 32, table 10).

On the other hand, dry matter content in cultivar Korridor in treatments 5 °C and ice was decreased than at harvest condition. But it did not vary between treatments 5 °C and ice. In cultivar Kolibri, the content was greatly reduced in 0 °C and ice treatments than at harvest and 0 °C.

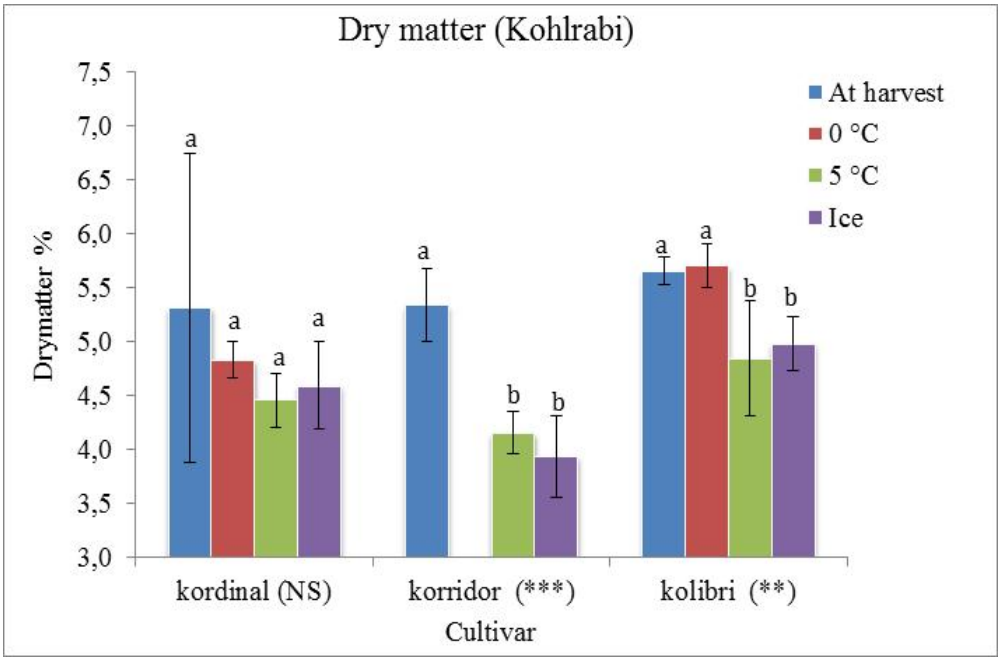

Figure 32 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on dry matter contents of Kohlrabi cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at $p = 0.05$

NS non-significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

*** Significant at $p \leq 0.001$

4.3.1.2 Response of Kohlrabi cultivars on dry matter contents in different temperature conditions

At harvest and 5 °C storage condition, dry matter content among three cultivars was not too varied ($p < 0.05$).

At treatment 0 °C, cultivar Kolibri contained higher dry matter content than Kordinal (figure 33, table 11). Similarly, significantly lower dry matter content was recorded in Korridor than in Kordinal and Kolibri in ice. But no significant difference was observed between Kordinal and Kolibri (figure 33, table 11).

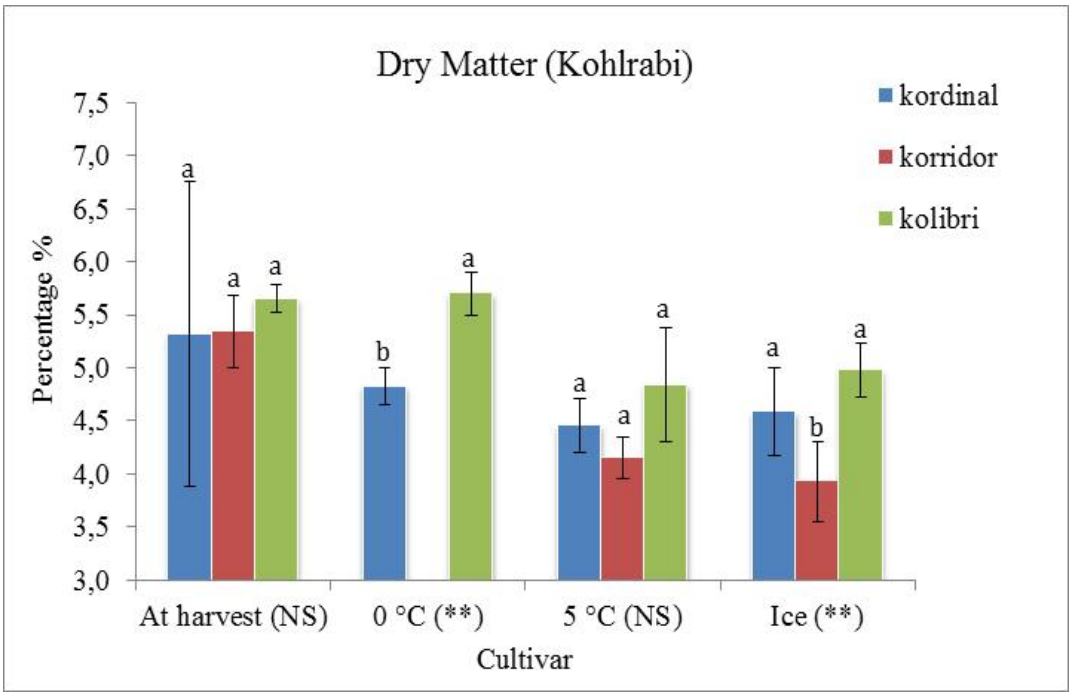

Figure 33 Response of Kohlrabi cultivars on dry matter content in different storage conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at p = 0.05.

NS non-significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

4.3.2 Antioxidant activity

4.3.2.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on antioxidant activity (FRAP) contents of Kohlrabi cultivars

Antioxidant activity in cultivar Kordinal did not vary at harvest and other three (0 °C, 5 °C and ice) storage treatments ($p < 0.05$). In cultivar Korridor, the content was higher at harvest than at 5 °C and ice storage condition. In case of Kolibri, it was shrinked at 5 °C treatment than at harvest and 0 °C. But it did not vary between 5 °C and ice and at harvest and 0 °C treatments (figure 34, table10).

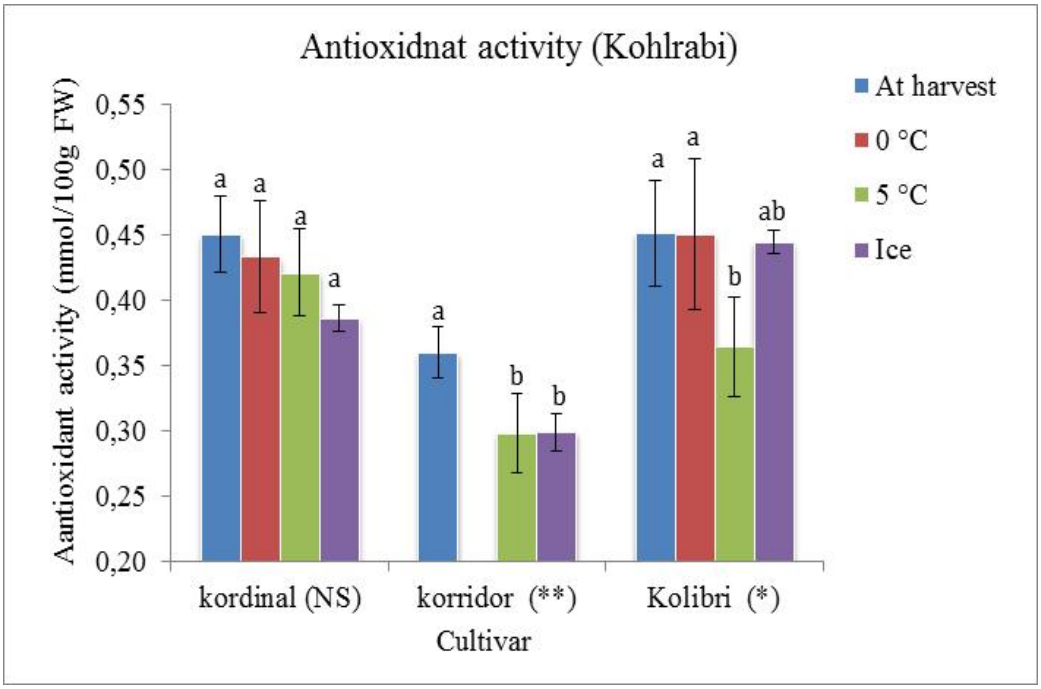

Figure 34 Effect of temperature on FRAP content antioxidant activity at harvest and between treatments (0 °C, 5 °C and ice) in Kohlrabi cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same latter within the group are not significantly different at $p = 0.05$

NS non-significant at $p \leq 0.05$

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

4.3.2.2 Response of Kohlrabi cultivars on antioxidant activity (FRAP) contents in different temperature conditions

At harvest, the antioxidant activity in cultivar Korridor was lower (0.36 mmol/100g FW) as compared to cultivar Kordinal and Kolibri at ($p < 0.05$) but it did not vary between Kordinal and Kolibri.

In case of 5 °C treatment, it was lower in cultivar Korridor compared to Kordinal while there was significant variance between Korridor and Kolibri (figure 35, table 11). Similarly in treatment ice, it was different among three cultivars; the highest content of it was recorded in Kolibri followed by Kordinal and the lowest in corridor.

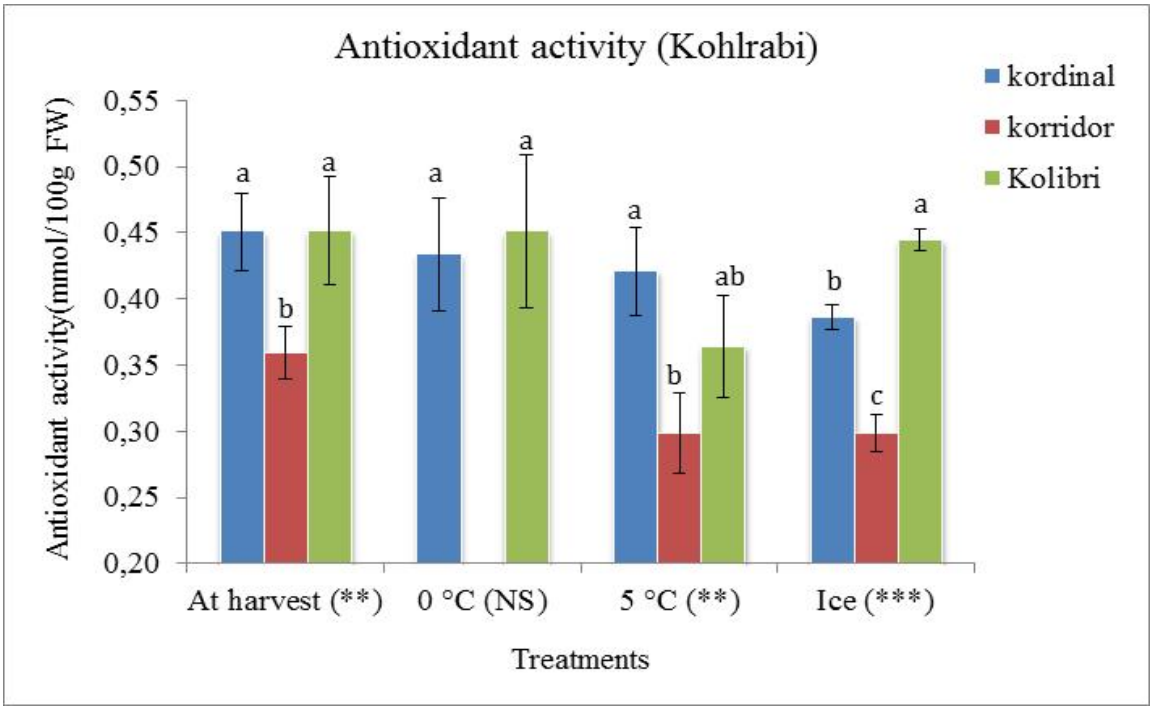

Figure 35 Response of Kohlrabi cultivars on antioxidant activity in different storage conditions.

Data are the mean value of four replications, n = 4. Error bars are the standard deviation. Bars with same letter within group are not significantly different at $p = 0.05$.

NS non-significant at $p \leq 0.05$

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

*** Significant at $p \leq 0.01$

4.3.3 Total Phenol

4.3.3.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) on total phenol contents of kohlrabi cultivars

Total phenol content in cultivar Kordinal, at harvest was not significantly different as compared with other three treatments 0 °C, 5 °C and ice. However, it was lower (33.99 mm GAE/100 FW) in ice as compared to 0 °C, 5 °C ($p < 0.05$). Total phenol content in cultivar Korridor was not statistically different among at harvest, 0 °C and ice treatments. In cultivar Kolibri, total phenol content was not different among four treatments (figure 36, table 10).

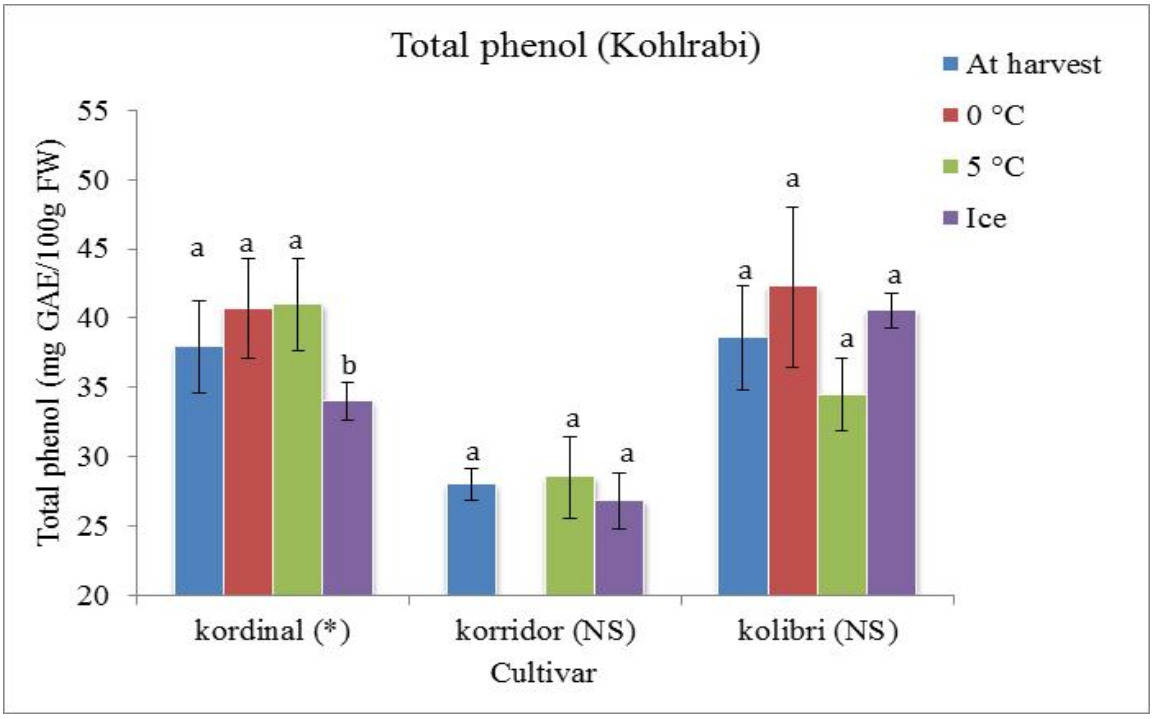

Figure 36 Effect of temperature on total phenol contents at harvest and between treatments in Kohlrabi cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at $p = 0.05$.

NS non-significant at $p \leq 0.05$

* Significant at $p \leq 0.05$

4.3.3.2 Response of Kohlrabi cultivars on total phenol contents in different temperature conditions

At harvest condition, total phenol content was lower in cultivar Korridor (27.98 mg GAE/100 FW) than in Kordinal and Kolibri where the latter two did not vary significantly at ($p < 0.05$). At 0 °C treatment, total phenol content was not statistically different between Kordinal and Kolibri (figure 37, table 11).

Total phenol content in 5 °C was different among three cultivars ($p < 0.05$) with the highest in Kordinal (41.00 mg GAE/100 FW) followed by Kolibri (34.50 mg GAE/100 FW) and the lowest in Korridor (28.51 mg GAE/100 FW). Kolibri demonstrated the significantly highest total phenol content and least in Korridor while Kordinal demonstrated the value lying in between the two in ice treatment.

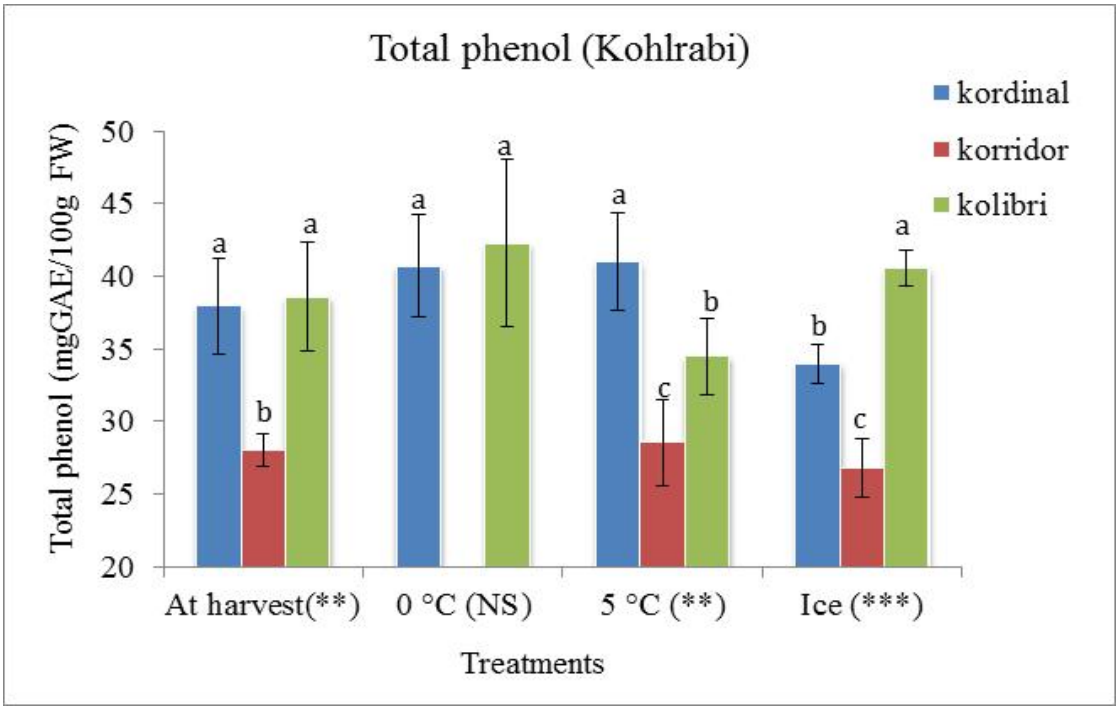

Figure 37 Response of Kohlrabi cultivars on total phenol contents in different temperature conditions. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at $p = 0.05$

NS non-significance at $p \leq 0.05$

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

*** Significant at $p \leq 0.001$

4.3.4 L- ascorbic acid

4.3.4.1 Effect of temperature (at harvest, 0 °C, 5 °C and ice) in L-ascorbic acid content of Kohlrabi cultivars

L-ascorbic acid content in cultivar Kordinal was less in three (0 °C, 5 °C and ice) storage conditions than at harvest ($p < 0.05$), but the significant variation among 0 °C, 5 °C and ice was not recorded. In cultivar Korridor, it was shrinked in ice than at harvest condition. However, at 5 °C, it was not statistically different than at harvest and ice (figure 38, table 10) and it was less in ice than at harvest and 5 °C treatments in Kolibri also.

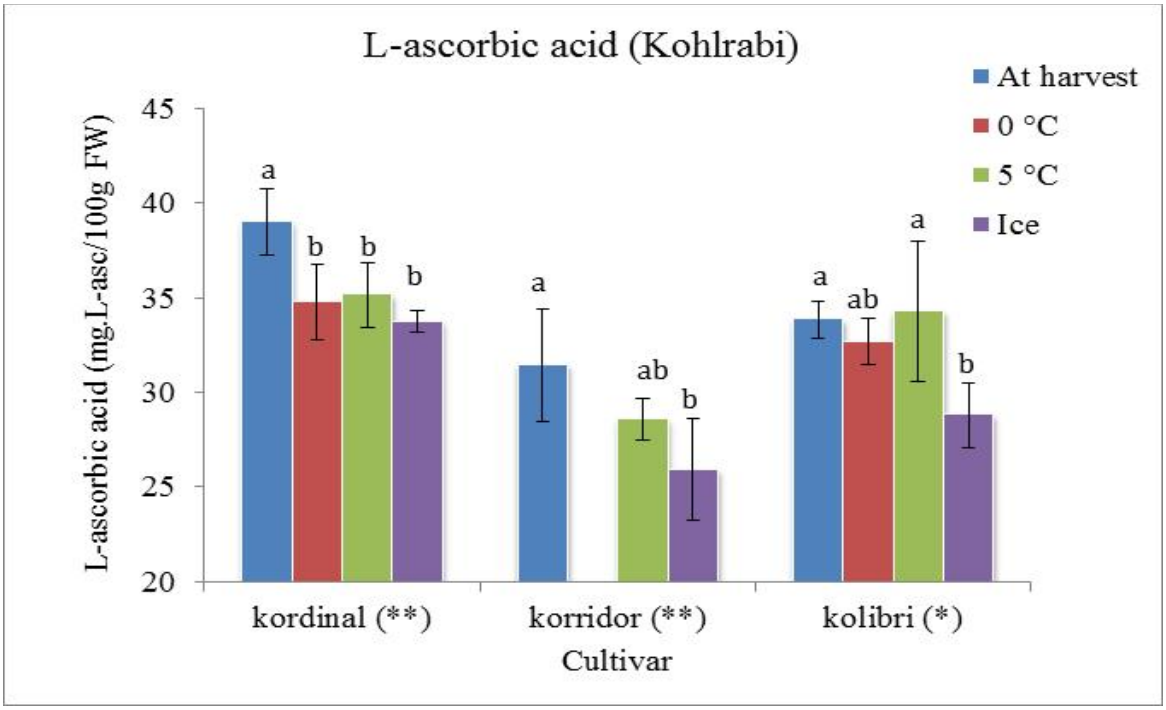

Figure 38 Effect of temperature on L-ascorbic acid contents at harvest and between treatments (0 °C, 5 °C and ice) in Kohlrabi cultivars. Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter within group are not significantly different at $p = 0.05$.

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$

4.3.4.2 Response of Kohlrabi cultivars on L-ascorbic acid contents in different temperature conditions

L-ascorbic acid content at harvest was found higher (39.02 mg L-asc/100g FW) in Kordinal than in other two cultivars. But, it did not vary greatly between Korridor (31.44 mg L-asc/100g FW) and Kolibri (34.80 mg L-asc/100g FW) at ($p < 0.05$). In 5 °C treatment, significantly lower value (28.57 mg. L-asc/100g) was observed in Korridor than other two cultivars but no significant variance was found between Kordinal (35.14 mg L-asc/100g FW) and Kolibri (34.30 mg L-asc/100g FW). In ice, the content of L-ascorbic acid was higher in Kordinal than other two cultivars (figure 39, table 11).

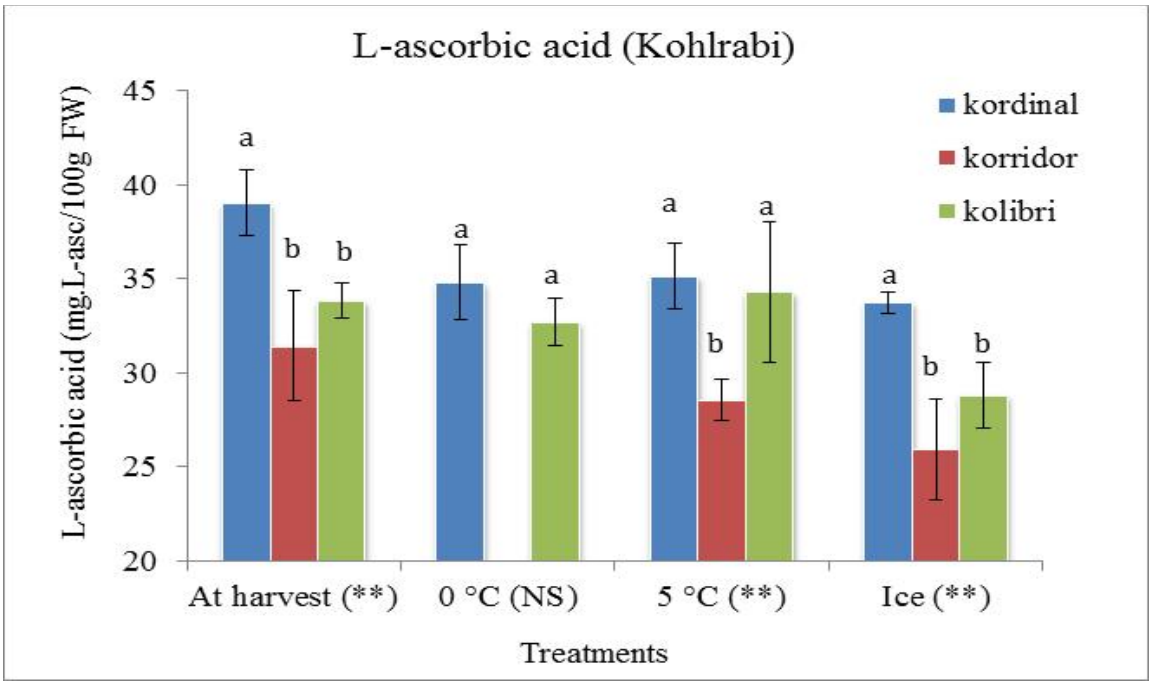

Figure 39 Response of Kohlrabi Cultivars on L-ascorbic acid contents in different temperature conditions.Data are the mean value of four replications, n = 4. Error bars are the standard deviation of the mean. Bars with same letter are not significantly different at $p = 0.05$.

NS non-significance at $p \leq 0.05$

** Significant at $p \leq 0.01$

Table 6. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) contents between at harvest, 0 °C, 5 °C and ice treatments in cauliflower cultivars.

Cultivar	Treatments	Parameters			
		DM (%)	AA (mmol/100g FW)	TP (mgGAE/100g FW)	L-AA(mg.L-asc/100g FW)
Flamenco	At harvest	7.41^{a} ±0.23	0.30^{b} ±0.03	44.92^{c} ±4.35	55.64^{b} ±6.34
	0 °C	6.70^{ab} ±0.49	0.68^{a} ±0.17	74.39^{ab} ±10.29	66.54^{ab} ±5.85
	5 °C	6.46^{b} ±0.23	0.78^{a} ±0.09	85.39^{a} ±3.63	65.64^{ab} ±4.64
	Ice	5.54^{c} ±0.39	0.57^{a} ±0.11	64.21^{b} ±7.50	70.33^{a} ±3.72
	LSD 5 %	0.53	0.20	12.33	7.98
Nemo	At harvest	7.50^{a} ±0.15	0.30^{b} ±0.06	44.04^{b} ±4.02	51.62^{b} ±3.88
	0 °C	7.53^{a} ±0.48	0.55^{a} ±0.14	61.97^{a} ±8.81	62.64^{a} ±5.69
	5 °C	6.62^{b} ±0.35	0.60^{a} ±0.10	67.46^{a} ±3.60	58.75^{ab} ±1.55
	Ice	5.59^{c} ±0.12	0.19^{b} ±0.03	39.14^{b} ±2.94	62.07^{a} ±4.69
	LSD 5 %	0.46	0.13	7.32	7.41
Celio	At harvest	8.52^{a} ±0.32	0.27^{b} ±0.03	41.66^{c} ±1.56	71.37^{a} ±4.33
	0 °C	8.56^{a} ±0.27	0.46^{a} ±0.04	61.28^{a} ±2.19	75.18^{a} ±7.01
	5 °C	8.47^{a} ±0.23	0.39^{a} ±0.05	58.47^{ab} ±1.87	65.62^{b} ±2.95
	Ice	7.59^{b} ±0.27	0.39^{a} ±0.04	54.57^{b} ±3.10	68.70^{b} ±3.49
	LSD 5 %	0.39	0.07	4.01	6.47

Data are expressed as mean ± standard deviation.

Means with different letters, within column for each cultivar indicate significant difference at p= 0.05 (LSD 5%,, Tukey`s test).

Table 7. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) between cauliflower cultivars stored on treatments (0 °C, 5 °C, and ice) and at harvest condition

Treatments	Cultivars	Parameters			
		DM (%)	AA (mmol/100gFW)	TP (mgGAE/100gFW)	L-AA (mg.L-asc/100gFW)
At harvest	Flamenco	7.41^{b} ±0.23	0.30^{a}±0.03	44.92^{a} ±4.35	55.64^{b}±6.34
	Nemo	7.50^{b} ±0.15	0.30^{a}±0.06	44.04^{a}±4.02	51.62^{b}±3.88
	Celio	8.52^{a} ±0.32	0.27^{a}±0.03	41.66^{a} ±1.56	71.37^{a}±4.33
	LSD 5 %	0.49	0.08	7.40	8.82
0 °C	Flamenco	6.70^{b}±0.49	0.68^{a} ±0.17	74.39^{a}±10.29	66.54^{ab}±5.85
	Nemo	7.53^{b} ±0.48	0.55^{a} ±0.14	61.97^{a} ±8.81	62.64^{b}±5.69
	Celio	8.56^{a} ±0.27	0.46^{a} ±0.04	61.28^{a} ±2.19	75.18^{a} ±7.01
	LSD 5 %	0.89	0.26	15.98	9.28
5 °C	Flamenco	6.46^{b} ±0.39	0.78^{a} ±0.09	85.39^{a} ±3.63	65.64^{a}±4.64
	Nemo	6.62^{b} ±0.35	0.60^{b}±0.10	67.46^{b} ±3.60	58.75^{b}±1.55
	Celio	8.47^{a} ±0.23	0.39^{c} ±0.05	58.47^{c} ±1.87	65.62^{a} ±2.95
	LSD 5 %	0.46	0.14	3.28	6.54
Ice	Flamenco	5.54^{b} ±0.39	0.57^{a} ±0.11	64.21^{a} ±7.50	70.33^{a} ±3.72
	Nemo	5.59^{b} ±0.12	0.19^{c}±0.03	39.14^{b} ±2.94	62.07^{b} ±4.69
	Celio	7.59^{a} ±0.27	0.39^{b} ±0.04	54.57^{a} ±3.10	68.70^{ab}±3.49
	LSD 5 %	0.56	0.14	9.17	7.79

Data are expressed as mean ± standard deviation.

Means with different letters within column indicate significant difference at p= 0.05 (LSD 5%, Tukey`s test).

Table 8. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) parameters between at harvest, 0 °C, 5 °C and ice treatments in Cabbage cultivars.

Cultivar	Treatments	Parameters			
		DM (%)	AA (mmol/100gFw)	TP (mgGAE/100FW)	L-AA (mg.L-asc/100gFW)
Bartolo	At harvest	9.61^{a} ±0.27	0.42^{a} ±0.06	41.16^{a} ±3.87	44.63^{a} ±3.29
	0 °C	9.51^{a} ±0.44	0.52^{a} ±0.11	49.24^{a} ±6.62	46.27^{a} ±2.18
	5 °C	9.58^{a} ±0.49	0.49^{a} ±0.04	46.91^{a} ±3.69	44.13^{a} ±1.06
	Ice	9.00^{a} ±0.16	0.50^{a} ±0.09	47.66^{a} ±2.49	42.48^{a} ±3.11
	LSD 5%	0.48	0.13	7.80	3.69
Castello	At harvest	7.20^{a} ±0.33	0.22^{b} ±0.01	29.12^{b} ±0.81	34.40^{a} ±0.99
	0 °C	6.93^{ab} ±0.44	0.46^{a} ±0.05	45.44^{a} ±2.12	36.61^{a} ±2.75
	5 °C	5.85^{b} ±0.95	0.47^{a} ±0.05	46.53^{a} ±5.22	33.88^{a} ±1.64
	Ice	6.37^{ab} ±0.20	0.47^{a} ±0.06	44.77^{a} ±2.79	32.77^{a} ±1.76
	LSD 5%	0.90	0.08	5.68	3.04
Rovite	At harvest	8.57^{a} ±0.19	1.66^{a} ±0.13	153.05^{a} ±11.11	36.50^{b} ±1.12
	0 °C	8.76^{a} ±0.38	1.89^{a} ±0.26	165.88^{a} ±18.37	36.73^{b} ±0.95
	5 °C	8.36^{a} ±0.21	1.83^{a}±0.22	164.51^{a} ±20.33	40.34^{ab} ±2.65
	Ice	8.44^{a} ±0.23	1.92^{a}±0.14	166.89^{a} ±13.88	44.33^{a} ±3.43
	LSD 5%	0.47	0.31	23.45	3.49

Data are expressed as mean ± standard deviation.

Means with different letters within column for each cultivar, indicate significant difference at $p = 0.05$

(LSD 5%, Tukey`s test).

Table 9. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) between Cabbage cultivars stored on treatments (0 °C, 5 °C, and ice) and at harvest condition

Treatments	Cultivars	Parameters			
		DM (%)	AA (mmol/100gFW)	TP (mgGAE/100gFW)	L-AA (mg.L-asc/100gFW)
At harvest	Bartolo	9.61^{a} ±0.27	0.42^{b} ±0.06	41.16^{b} ±3.87	44.63^{a} ±3.29
	Castello	7.20^{c} ±0.33	0.22^{c} ±0.01	29.12^{c} ±0.81	34.40^{b} ±0.99
	Rovite	8.57^{b} ±0.19	1.66^{a} ±0.13	153.05^{a} ±11.11	36.50^{b} ±1.12
	LSD 5 %	0.31	0.15	11.69	3.96
0 °C	Bartolo	9.51^{a} ±0.44	0.52^{b} ±0.11	49.24^{b} ±6.62	46.27^{a} ±2.18
	Castello	6.93^{b} ±0.44	0.46^{b} ±0.05	45.44^{b} ±2.12	36.61^{b} ±2.75
	Rovite	8.76^{a} ±0.38	1.89^{a} ±0.26	165.88^{a} ±18.37	36.73^{b} ±0.95
	LSD 5 %	0.78	0.26	18.25	3.22
5 °C	Bartolo	9.58^{a} ±0.49	0.49^{b} ±0.04	46.91^{b} ±3.69	44.13^{a} ±1.06
	Castello	5.85^{b} ±0.95	0.47^{b} ±0.05	46.53^{b} ±5.22	33.88^{c} ±1.64
	Rovite	8.36^{a} ±0.21	1.83^{a} ±0.22	164.51^{a} ±20.33	40.34^{b} ±2.65
	LSD 5 %	1.07	0.23	20.44	3.67
Ice	Bartolo	9.00^{a} ±0.16	0.50^{b} ±0.09	47.66^{b} ±2.49	42.48^{a} ±3.11
	Castello	6.37^{b} ±0.20	0.47^{b} ±0.06	44.77^{b} ±2.79	32.77^{b} ±1.76
	Rovite	8.44^{b} ±0.23	1.92^{a} ±0.14	166.89^{a} ±13.88	44.33^{a} ±3.43
	LSD 5 %	0.98	0.20	15.7	3.2

Data are expressed as mean ± standard deviation.

Means with different letters within column indicate significant difference at $p = 0.05$ (LSD 5%, Tukey`s test).

Table 10. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) parameters between at harvest, 0 °C, 5 °C and ice treatments in Kohlrabi cultivars

Cultivar	Treatments	Parameters			
		DM (%)	AA (mmol/100gFW)	TP (mgGAE/100FW)	L-AA (mg.L-asc/100gFW)
Kordinal	At harvest	5.31^{a} ±1.44	0.45^{a} ±0.03	37.92^{ab} ±3.35	39.02^{a} ±1.76
	0 °C	4.83^{a} ±0.17	0.43^{a} ±0.04	40.70^{a} ±3.56	34.80^{b} ±2.00
	5 °C	4.46^{a} ±0.25	0.42^{a} ±0.03	41.00^{a} ±3.32	35.14^{b} ±1.74
	Ice	4.59^{a} ±0.41	0.39^{a} ±0.01	33.99^{b} ±1.33	33.75^{b} ±0.57
	LSD 5%	1.22	0.04	3.12	1.92
Korridor	At harvest	5.34^{a} ±0.34	0.36^{a} ±0.02	27.98^{a} ±1.13	31.44^{a} ±2.95
	0 °C	-	-	-	-
	5 °C	4.15^{b} ±0.20	0.30^{b} ±0.03	28.51^{a} ±2.94	28.57^{ab} ±1.08
	Ice	3.93^{b} ±0.38	0.30^{b} ±0.01	26.81^{a} ±2.00	25.93^{b} ±2.71
	LSD 5%	0.39	0.04	4.14	3.36
Kolibri	At harvest	5.65^{a} ±0.13	0.45^{a} ±0.04	38.58^{a} ±3.73	33.84^{a} ±0.97
	0 °C	5.70^{a} ±0.21	0.45^{a} ±0.06	42.27^{a} ±5.78	32.70^{ab} ±1.22
	5 °C	4.84^{b} ±0.54	0.36^{b} ±0.04	34.50 ^{a}±2.64	34.30^{a} ±3.71
	Ice	4.98^{b} ±0.25	0.44^{ab} ±1.73	40.57^{a} ±1.24	28.81^{b} ±1.73
	LSD 5%	0.44	0.07	6.59	3.59

Data are expressed as mean ± standard deviation.

Means with different letters within column for each cultivar, indicate significant difference at $p = 0.05$

(LSD 5%, Tukey`s test).

Table 11. Effect of temperature on dry matter (DM), Antioxidant activity (FRAP), total phenol (TP) and L-ascorbic acid (L-AA) between Kohlrabi cultivars stored at treatments (0 °C, 5 °C, and ice) and at harvest condition.

		Parameters			
Treatments	Cultivars	DM (%)	AA (mmol/100gFW)	TP (mg GAE/100gFW)	L-AA (mg.L-asc/100gFW)
At harvest	Kordinal	5.31^{a} ±1.44	0.45^{a} ±0.03	37.92^{ab} ±3.35	39.02^{a} ±1.76
	Korridor	5.34^{a} ±0.34	0.36^{a} ±0.02	27.98^{a} ±1.13	31.44^{a} ±2.95
	Kolibri	5.65^{a} ±0.13	0.45^{a} ±0.04	38.58^{a} ±3.73	33.84^{a} ±0.97
	LSD 5 %	1.56	0.06	5.98	4.09
0 °C	Kordinal	4.83^{b} ±0.17	0.43^{a} ±0.04	40.70^{a} ±3.56	34.80^{b} ±2.00
	Korridor	-	-	-	-
	Kolibri	5.70^{a} ±0.21	0.45^{a} ± 0.06	42.27^{a} ±5.78	32.70^{ab} ±1.22
	LSD 5 %	0.38	0.08	7.99	2.11
5 °C	Kordinal	4.46^{a} ±0.25	0.42^{a} ±0.03	41.00^{a} ±3.32	35.14^{a} ±1.74
	Korridor	4.15^{b} ±0.20	0.30^{b} ±0.03	28.51^{c} ±2.94	28.57^{b} ±1.08
	Kolibri	4.84^{b} ±0.54	0.36 ±0.04	34.50 ^{b} ±2.64	34.30^{a} ±3.71
	LSD 5 %	0.70	0.06	5.38	4.52
Ice	Kordinal	4.59^{a} ±0.41	0.39^{a} ±0.01	33.99^{b} ±1.33	33.75a ±0.57
	Korridor	3.93^{b} ±0.38	0.30^{b} ±0.01	26.81^{a} ±2.00	25.93^{b} ±2.71
	Kolibri	4.98^{a} ±0.25	0.44^{b} ±1.73	40.57^{a} ±1.24	28.81^{b} ±1.73
	LSD 5 %	0.38	0.02	1.97	3.72

Data are expressed as mean ± standard deviation.

Means with different letters within column indicate significant different at P≤0.05 (LSD test, and Tukey`s test).

5 DISCUSSION

5.1 Dry matter content

Dry matter of plant product is solid substance or mass without liquid. It is calculated by drying out the water from the sample. Dry matter content comprises the carbohydrates, fats, proteins, vitamins, minerals and antioxidants, mostly fiber contributing substances in the sample.

In the present study, there was loss of dry matter content in cauliflower and the proportion of loss was inconsistent within variety and treatments. Substantial reduction in dry matter content was observed in ice treatment. There was relatively high loss of dry matter (≥25 %) in Flamenco and Nemo but it was less (>10 %) in Celio (table 6). This stud the highest dry matter content was recorded in Celio followed by Nemo and the similar trend has been demonstrated by (Gajewski 2001; Stanistaw et al. 2006) where the highest dry matter was reported from the curd in Romanesco followed by green and white. In other study, 11% to 31 % losses of dry matter content in Brussels sprout, swedes, carrots and peas have been reported at blanching treatment (Acheson & Williams 1983; Berg 2009). Similarly in present study, pronounced loss in dry matter content was recorded in cabbage cultivar Castello and kohlrabi cultivar Korridor and Kolibri at 5 ^{o} C and ice storage. The losses in ice storage may be due to the leaching of water-soluble low molecular weight components from the sample. Wennberg et al (2006) also reported the loss of dry matter content in white cabbage during wet treatment.

5.2 Antioxidant activity

Due to the preventive role of antioxidants against oxidation of free radicals in the body, it is proved that antioxidants play an important role in preventing many degenerative and chronic diseases (Kurilich et al. 1999).

In the current study, variation in the antioxidant activity among Cauliflower, Cabbage and Kohlrabi crops and their cultivars and treatments have been noticed. Ou et al. (2002) and

Halvorsen et al (2002) also reported the intra-varietal and intra-species variation of the antioxidant activity in vegetables, fruits, berries and other food plants. The broccoli stored in 1 °C and 5 °C expressed the increase in contents of antioxidant activity as compared to the fresh broccoli florets, although, the latter resulted in high weight loss. The effect of controlled atmosphere showed negligible significance (Wold et al. 2006). Antioxidant activity was found to be varying from 92% in turmeric and kachnar to as low as 13% in radish and long melon among the 34 vegetables under investigation (Gazzani et al. 1998). Antioxidant activity in Cauliflower cultivars Flamenco and Celio was found to be significantly increased during 0 °C, 5 °C and ice storage conditions than at harvest ($P \leq 0.05$) (Figure 18. and table 6). Kaur & Kapoor (2002) have grouped cauliflower in a group of low antioxidant activity among 34 vegetables taken in account. So it suggests genetically low profile of antioxidant activity and increase during the storage conditions. Whereas in cultivar Flamenco, the antioxidant activity was found to be increased by more than 2.5 fold during storage at 5 °C, more than 2 fold during 0 °C and almost twice in ice. The reason behind it might be due to the metabolic reactions and synthesis which go higher and faster at higher temperature (5 °C) compared to lower temperature (0 °C) and it might have favoured the biosynthesis of antioxidants within the plant metabolism. In agreement to this, an alteration in the chemical composition of cauliflower during storage results the curds to respires very fast lead them to enhance the biosynthesis of phytochemicals related to antioxidants (Hansen et al. 1995; Rodrigues & Rosa 1999). Likewise, high antioxidants have been reported in mushroom, white cabbage and cauliflower by the effect of thermal treatment (Gazzani et al. 1998). A large variation in the amount of antioxidants activity is found among the family *Brassicaceae* ranging from cabbage (0.09) to kale (2.34) mmol/100g (Halvorsen et al. 2002). The antioxidant activity in some apple cultivars 'Delicious' and 'Granny smith' was found to have been increased by up to ten times during the first two month storage at -1 °C (Curry 1997).

In case of Cabbage cultivar Castello, antioxidant activity increased during three storage conditions than at harvest. At the same time, cultivar Rovite revealed significantly the highest antioxidant activity than other two Bartolo and Castello cultivars during four-treatment conditions (figure 26 and 27). The result showed that, cabbage cultivar Rovite expressed highest amount of antioxidant activity than white (Bartolo and Castello) cabbages because of its red color where anthocyanin pigment imparting the red color acts as antioxidant activity (Drabent et al. 1999; Sadilova et al. 2006). Anthocyanin is phenolic compound which Vinson et al. (1998)

mentioned phenols as the source of antioxidant. Similarly,Giusti et al. (1999), Jahangir et al. (2009); Wu & Prior (2005a) also mentioned the presence of cyanidin derivatives in red cabbage which is the derivative of anthocyanin that enhancing the antioxidant property. Chun et al.(2004) mentioned cyanidin as the main factor enhancing governing the antioxidant property in red cabbage. The results of other contemporary researchers Velioglu, Y. et al. (1998); Wang et al. (1997), also concluded that the vegetables rich in anthocyanin possess strong anti-oxidant property. Thus, the high antioxidant activity of red cabbage (Rovite) in the present study can be traced back to its genetic base.

On the other hand, Kaur & Kapoor (2002) reported white cabbage to lie among the vegetables possessing moderate antioxidant activity (60-70%). Moreno et al. (2010) supported the presence of greater amount of anthocyanin in `purple head` broccoli than green varieties.

In case of Kohlrabi cultivars Korridor and Kolibri, antioxidant activity was decreased significantly during 5 ^{o}C and ice storage than at harvest condition while in Kordinal, it was not significant (figure 34). Kohlrabi cultivar Korridor revealed significantly lower antioxidant activity than other two cultivars during at harvest, 5 °C and ice treatments. But in 5 °C Kordinal contained highest antioxidant activity than Kolibri while opposite result was seen in treatment ice (figure 35).

There may be various factors causing the variation in antioxidant activities among treatments and cultivars. Genetic make-up of the crop, species, variety, growing condition, maturity at harvest and the interaction of genetic and environmental factors affect in the phytochemicals or antioxidant activity present in plant food (Moreno et al. 2006).

The variation in the antioxidant contents in brassica vegetables also reviewed by de Pascual-Teresa & Sanchez-Ballesta (2008); Hale et al. (2001); and Podsedek (2007) and they concluded that occurrence of the variation in antioxidants was due to the crop cultivars and treatments factors as well. Cultivar dependent antioxidant activity in apple and blueberry were reported by van der Sluis et al. (2001) and Ehlenfeldt & Prior (2001) respectively. Many researchers Cao et al. (1996); Ou et al. (2002); Zhou & Yu (2006) have been also reported the similar findings that this activity is cultivar based in different vegetables. Unripe green tomatoes expressed

remarkably less antioxidants than ripe fruits which states the maturity stage as a factor affecting antioxidants (Wold et al. 2007).

The antioxidant activity of the vegetables depends upon its phenolic contents whose increment or decrement relies upon another phytochemicals too. The statistical analysis shows a highly positive correlation between the total phenolics and antioxidant activity (Kaur & Kapoor 2002; Velioglu, Y. et al. 1998)

5.3 Total Phenol

In this experiment total phenol content varied according to crop, cultivars and treatments. In cauliflower Flamenco, total phenol content was increased more than by 90 %, 65.60 % and 42.95 % during 5 ^{o}C, 0 ^{o}C and ice respectively than at harvest condition. But in case of Nemo, it was increased by 53.17 % and 40.71 % during 5 ^{o}C and 0 ^{o}C while in ice it was decreased by 11.12 % than at harvest condition. Similarly in Celio total phenol content was significantly increased during 5 ^{o}C, 0 ^{o}C and ice storage than at harvest conditions (figure 20 and table 6).

However, at 5 ^{o}C treatment, Flamenco contained significantly the highest total phenol content followed by Nemo and Celio (Figure 21, Table 7).

Total phenol content in Cabbage cultivar Bartolo and Rovite did not vary significant during all treatments. While, in Castello it was significantly increased during other three treatments than at harvest condition (Figure 28 and table 8). (Kaur & Kapoor 2002) reported that the total phenolic content varied from 34 to 400 mg /100g FW among the 36 common vegetables taken into account while that of cabbage was less than 100 mg/100g FW.

During three storage conditions 0 ^{o}C, 5 ^{o}C and ice; Rovite demonstrated the significantly highest total phenol content than the other two cultivars. Colored cultivar of cabbage (Rovite) demonstrated the highest total phenol content than other white cultivars because of its red color. This result also followed the same tendency with (Chun et al. 2004; Proteggente et al. 2002). Red color is due to high concentration of anthocyanin contents that adds the phenolic activities. Chigurupati et al. (2002) mentioned the cyanidin as the major coloring pigments in the red

cabbages. Vinson et al. (1998) also demonstrated the highest concentration of total phenols in beet, red onion, broccoli and kidney beans. In the same paper, Vinson et al. (1998) also mentioned that red onion contains more phenols than yellow onions because of extra phenolic anthocyanin in red onion.

But in Kordinal it was significantly lowest in treatment ice than other conditions (Figure 36 table 10). At treatment 5 ^{o}C, it was significantly highest in Kordinal followed by Kolibri and least in Korridor. However, in ice it was significantly highest in Kolibri followed by Kordinal and least in Korridor (figure 37 and table 11).

Holcroft & Kader (1999) reported an increase in phenolic compounds in strawberry during storage at 5 ^{o}C for ten days. Similarly, the current research demonstrated two times increase of total phenol content in cauliflower cultivar Flamenco stored at 5 ^{o}C for 40 days (figure 20, table 7) Phenolic compounds present in the plant acts as antioxidant for human body (Meulenberg 2009; Parr & Bolwell 2000).

Gulcin (2005); Velioglu, Y. S. et al. (1998); and Yen et al. (1993) reported that the direct positive correlation between phenolic compounds and antioxidant activity in their study done in many plants. Kaur & Kapoor (2002) found a positive and highly significant ($\gamma^2 = 0.6578$ at $p < 0.005$) relationship between the total phenolics and antioxidant activity among 34 vegetables under study. Similarly, Japanese studying the fresh vegetable extracts using Folin assay found the positive correlation, stating the minor contribution of proteins, ascorbate and the carotenoids (Tsushida et al. 1994). Moreover, a recent finding has also depicted a high correlation between antioxidant activity and phenolic compounds measured with DPPH and FRAP assays (Soengas et al. 2012). On the other hand, Ekrem KÖKSAL & GÜLÇİN (2008) reported the no positive correlation-relations between phenolic compounds and antioxidant activity on a study done in antioxidant activity in cauliflower. No any correlation was also found by Gazzani et al. (1998) between total phenol content and antioxidant activity on a study done in some dietary plant extracts.

Genotypic factors (cultivars), place of origin, environmental and agricultural practices and other various stresses and method of analysis may affect in the phenolic contents present in the

plants(Chun et al. 2004).Parr & Bolwell (2000) also reposted the same trend as study done in asparagus and that also supports to the current study.

5.4 L-ascorbic acid

L-ascorbic content in cauliflower Flamenco was significantly increased at treatment ice than at harvest condition although; it was not significantly different among 0 ^{o} C, 5 ^{o} C treatment ice. Similarly, no variation was observed among at harvest 0 ^{o} C and 5 ^{o} C ($P \leq 0.05$) (figure 22, table 6).

In Nemo it was significantly increased during 0 ^{o} C, and ice storage condition than at harvest condition. L-ascorbic content in Celio, was significantly decreased during 5 ^{o} C and ice storage condition than at harvest and 0 ^{o}C. In agreement to this findings, broccoli stored in 1 ^{o}C and 5 ^{o}C were found to have higher value of L-ascorbic acid compared to the freshly harvested broccoli florets (Wold et al. 2006).

Another study on the L-ascorbic acid content in Celio has reported to be highest and lowest in Flamenco as observed in freezer storage of cauliflowers (Volden et al. 2009a) which is quite similar to the present study where Nemo contained significantly the lowest L-ascorbic acid content than Flamenco and Celio during all four treatments although, fluctuation was observed between Flamenco and Celio (figure 23, table 7). The higher L-ascorbic acid in green cauliflower, medium in Romanesco and the lowest in white curd was depicted in another search by Gajewski (2001) from the study in Poland. Here, a previous researcher Davey et al. (2000) has concluded a reduction in the value of L-ascorbic acid upon blanching treatment.

In case of Cabbage, L-ascorbic acid content was not significantly varied during four treatments in Bartolo and Castello cultivars but it was significantly increased at ice than at harvest and 0 ^{o}C treatments (figure 25, table 8).

Bartolo depicted the significantly highest L-ascorbic acid content as compared to Castello and Rovite. In treatment 5 ^{o}C, Bartolo contained significantly highest L-ascorbic acid followed by Rovite and least in Castello. However, in treatment ice Castello contained significantly lower L-

ascorbic acid content than other Bartolo and Rovite but there was no variation of content between Bartolo and Rovite. Contrarily, Singh et al. (2006) demonstrated the highest Vitamin C content in red cabbage (24.38 mg/100g) ranging as low as 5.66 mg/100g fresh weight in three cultivated forms of cabbage namely: red, savoy and white. Similarly, Podsedek et al.(2006) agreed that the highest vitamin C content was observed in red cabbage and the least in white cabbage leaves ranging from 129 to 18 mg/100g.

L-ascorbic content in three cultivars of Kohlrabi responded differently to all four treatments. A study in line with the present study states that the kohlrabi stored without leaves at 0 ^{o}C and 99% RH prolongs the storage life up to 3 months preventing shriveling and toughening as compared to the kohlrabi stored at 0 ^{o}C with leaves for only 2 weeks (Hardenburg et al. 1986). Kohlrabi is strongly recommended to store at 0 ^{o}C to 5 ^{o}C for maintain the better quality and longer shelf life of kohlrabi (Escalona et al. 2003). At harvest and in ice treatment, Kordinal exhibited significantly the highest L-ascorbic content compared to Korridor and Kolibri (figure 24, table 8). In Korridor, L-ascorbic acid content was significantly decreased in treatment ice than at harvest condition while, it increased in freezing condition during the later period of storage (Jany et al. 2010) but L-ascorbic acid content in 5 ^{o}C did not vary with ice and at harvest condition (figure 23, table7).

A study by Lee & Kader (2000) confirms that the content of vitamin C in fruits and vegetables is governed by many factors as genotypic differences, climatic conditions, cultural practices, maturity and harvesting methods, postharvest handling procedures, the intensity of light during growing season and temperature management all contribute to the content of vitamin C.

6 CONCLUSION

From the present study, it can be concluded that the phytochemicals present in *Brassica* vegetables may vary depending upon their genetics and storage treatments. In order to get higher amount of concerned phytochemicals from the brassica vegetables, it is more important to select genotype with higher concentration of them. For instance, red cabbage contains highest amount of total phenols and antioxidant activity than white cabbage, cauliflower and kohlrabi. But cauliflower cultivars contain higher L-ascorbic acid content than cabbage and kohlrabi as their genetic potential. The green cauliflower Romanesco should be explored for its unique pyramidal shape and nutrient concentration.

Moreover, antioxidant activity and total phenolic contents in cauliflower increased noticeably during low temperature (0 °C and 5 °C) storage conditions. Similarly, these contents do not reduce so much in ice where Flamenco performed better than the other two cultivars. While in cabbage and kohlrabi, those contents could not increase significantly as in cauliflower. However, depending upon cultivars slight inconsistency was found.

Ice storage performed better for enhancing L-ascorbic acid content in Cauliflower cultivars. During transportation and storage of products, it is costly enough than to maintain the optimum low temperature. So from economic point of view, ice could be a better option. In Flamenco and Nemo, both 0 °C and ice storage increased L-ascorbic content.

L-ascorbic acid content could be enhanced in red cabbage by storing in ice but white cabbage and kohlrabi do not respond positively at that condition. Hence, it can be referred that ice storage could better preserve L-ascorbic acid in red cabbage. Ice can be a good storage alternative. So, further investigation is needed to observe the cost-effectiveness between storage in ice compared to 0 °C.

Kohlrabi is relatively average in nutrients concerned and very few researches are done whose nutrient potential should be explored and exploited to harnessed. It is relatively easy crop to store and lasts longer.

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