EFFECT OF PRETREATMENTS AND STORAGE TEMPERATURES ON PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF CARROT POWDER

A THESIS

BY

KATHIKA DAS

STUDENT ID.: 1405193

SEMESTER: JULY- DECEMBER, 2016

MASTER OF SCIENCE (MS)

IN

FOOD ENGINEERING AND TECHNOLOGY

DEPARTMENT OF FOOD ENGINEERING AND TECHNOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200, BANGLADESH

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JULY- DECEMBER, 2016

DEDICATED
TO MY
BELOVED PARENTS

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The Author

ABSTRACT

Drying of vegetable after chemical pretreatment has long been an effective method of preservation. The objective of this study was to find out suitable pretreatment and storage temperature for cabinet dried carrot powder based on physico-chemical and functional properties. Drying process was carried out for carrot cubes (0.3-0.5cm) using four blanching (80±2ºC) pretreatments such as blanching with 1% calcium chloride ($CaCl_2$), 0.2% potassium metabisulphite (KMS), 1% calcium chloride and 0.2% potassium metabisulphite ($CaCl_2$+KMS) combination and pure water. An untreated sample was considered as control. Then all the pretreated samples were dried in cabinet dryer at 60±2ºC temperature for 18 hours and the dried samples were ground as powder. The entire obtained carrot powder sample were packed in low density polyethylene and stored at three storage temperatures such as ambient temperature (20±2ºC), refrigeration temperature (4±2ºC) and freezing temperature (-10±2ºC). The dried samples were analyzed for physico-chemical properties in terms of moisture, ash, fat, protein, fiber, beta-carotene and color and functional properties such as degree of caking, water absorption index, rehydration ratio, swelling capacity, bulk density and solubility at 0 day, 30 days and 60 days of storage.

Results revealed that the moisture content of carrot powder treated with KMS and stored in freezing temperature was found to be lower than that of other pretreatments and storage temperatures. In case of fat, protein, ash, fiber and beta-carotene content, there were significant (at $p \leq 0.001$) effects of pretreatments and storage temperatures on carrot powder. Carrot powder treated with KMS and stored at freezing temperature was recorded to have better nutritional composition in terms of protein, fiber and beta-carotene compared to that of other pretreatments and storage temperatures.

On the other hand, all the functional properties of carrot powder were showed to be significantly (at $p \leq 0.001$) different due to different pretreatments and storage temperatures. Sample treated with KMS and stored at freezing temperature was reported to show better functional properties than that of other pretreatments and storage temperatures. The overall results indicated that physico-chemical and functional properties of cabinet dried carrot powder can be maintained well if the sample is treated with 0.2% KMS before drying and stored at freezing temperature.

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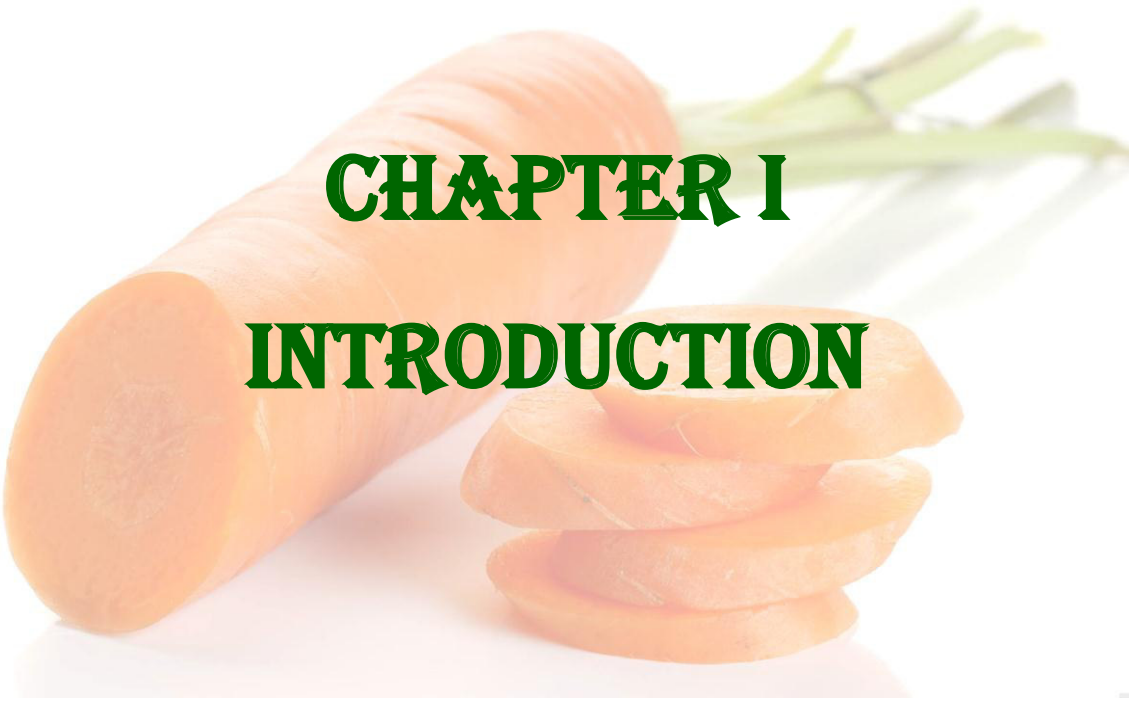
LIST OF ABBREVIATIONS

°C	= Degree Centigrade
µL	= Microliter
AACC	= Approved methods of American Association of Cereal Chemists
AOAC	= Association of Official Analytical Chemists
BBS	= Bangladesh Bureau of Statistics
$CaCl_2$	= Calcium chloride
cfu	= Colony Forming Unit
cm	= Centimeter
CV	= Coefficient of Variance
db	= Dry Basis
DV	= Daily Value
FAO	= Food and Agriculture Organization
g	= Gram
GI	= Glycemic Index
h	= Hour
K	= Kelvin
Kcal	= Kilocalorie
kg	= Kilogram
kj	= Kilojoule
KMS	= Potassium meta-bisulphate
LDPE	= Low density polyethylene
MBR	= Methylene blue reduction
mg	= Milligram
min	= Minute
ml	= Milliliter
nm	= Nanometer
OCC	= Open Column Chromatography
ppm	= Parts per million
rpm	= Revolution per minutes
µg	= Microgram
USDA	= United States Department of Agriculture



CHAPTER I

INTRODUCTION

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1.1 Background information

The demand for carrot powder is increasing rapidly both in domestic and in international market. The major portion of it used for preparation of convenience food. Thus, there exists a need to develop suitable technology for processing and preservation of this valuable produce.

Carrot (*Daucus carota L.*) is one of the most important fresh and processed vegetables usually red, purple, white, orange and yellow in color. Carrot belongs to the family *Umbelliferae*, genus *Daucus* and species *Carota.* It is mainly a temperate crop which is grown during the spring and the summer in temperate countries and during winter in tropical and subtropical countries of the world. The area of carrot cultivation was 81312 hectares with a total production of 3389663 tons in the world (FAO, 2006). In Bangladesh, the average yield of carrot is 35 t/ha, which is low compared to other carrot producing countries like Belgium (47.64 t/ha), Netherlands (61.87 t/ha) and Sweden (43.6 t/ha) (FAO, 2006). It is a very important root crop from the nutritional point of view since it has a great taste along with the highest β-carotene content among food products (Zielinska and Markowski, 2012); containing about 5–8 mg of β-carotene per 100 g (Decoteau, 2000). It is also a rich source of many bioactive compounds such as flavonoids, carotenoid and dietary fibre. Thus, carrots provide health benefits including strong antiseptic qualities, natural antioxidants and oxycarotenoids leutin having the anticancer activity such as colon cancer in man and woman (Sharma *et al.,* 2011; Jonas, 2011; Erenturk and Erenturk, 2007).

1.2 Problem statement

In Bangladesh, carrots are abundantly grown vegetable crops at peak season. But its availability reduces in off-season. Post-harvest lost limit the shelf-life of vegetables and nearly 17% of world's total production is lost (Togrul, 2006). Several studies have been performed to minimize deterioration after harvesting (Teferra F. Tadesse *et al*., 2015).

Drying is one of the oldest and most important methods to extend the shelf life of vegetables. It offers foods for consumers with diversity and shelf-life of perishable food is increased (Lewick *et al*., 1998; Roberts *et al.,* 2008). But during drying, browning

occurred in food through the Millard reaction that directly affect the organoleptical and nutritional quality of dehydrated products (Negi and Roy, 2011; Ghavidel and Davoodi, 2009).

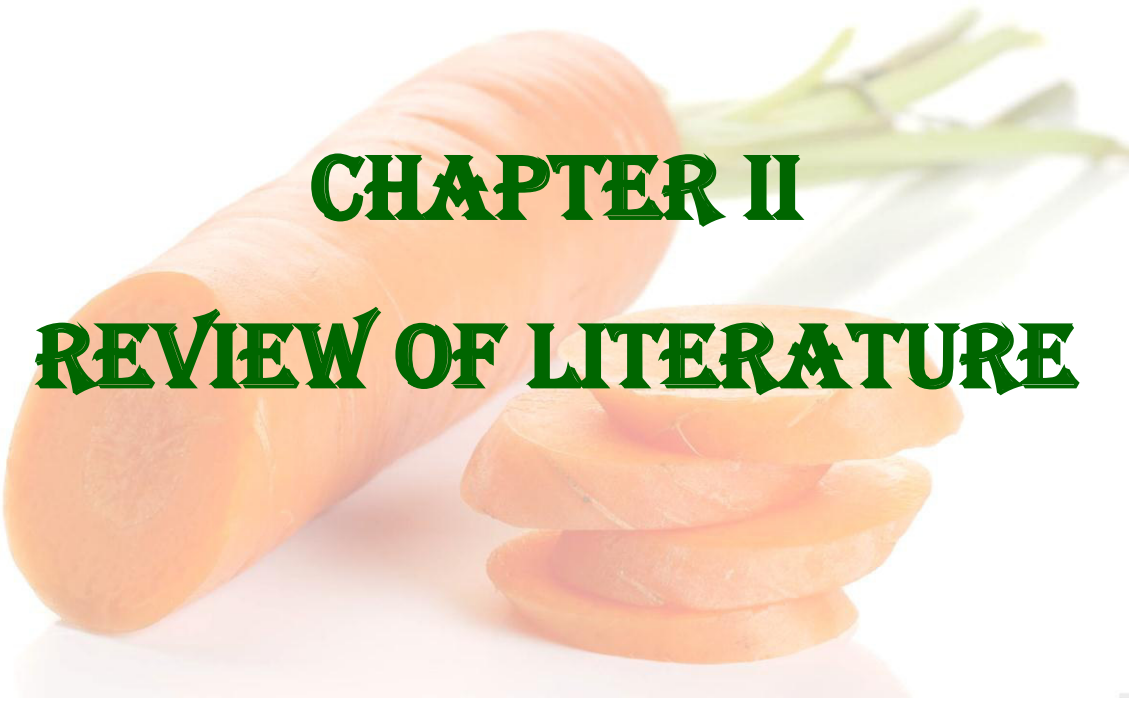
Several authors suggested that dried product quality is influenced by pretreatments and methods of dehydration (Kulkarni *et al.,* 1994; Waghmore *et al.,* 1999; Krokida *et al*., 1998). Pretreatment by blanching may reduce deterioration such as undesirable color and the product quality and storage life may increase as its main purpose is to neutralized enzymes. Other pretreatments include sulfiting, osmotic dewatering and immersing in diverse solutions as calcium chloride, gelatinized starch, citric acid, ascorbic acid and potassium metabisulphate (Lewicki *et al*., 1998). Very few attempt were taken to blanch carrot with chemical solution prior to dry in cabinet drier and evaluate the effect on physico-chemical and functional properties of carrot powder.

Carrot and its related products consumption is increasing day by day. Various studies have been done to utilize carrot in food such as dehydrated carrot, soups, pastries, sauces, cake, bread, biscuits, candy, beverages and halwa (Mridula, 2011). But a very few studies have been done for storage of carrot in powder form so that it can further be used as food ingredient.

1.3 Objectives of study

Based on the above mentioned consideration this work was carried out with a view to investigate the effects of pre-drying treatment (blanching with chemicals) and storage temperature on the prepared carrot powder. Thus the objectives are;

- To assess the effect of pretreatments on physico-chemical and functional properties of carrot powder during storage.
- To observe the changes in physico-chemical and functional properties of carrot powder during storage at three different storage temperatures.
- To find out the suitable pretreatment and storage temperature for carrot powder.



CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 Origin and production of carrot in worldwide

The carrot is a root vegetable, has a crisp texture when fresh. The most commonly eaten part of a carrot is a taproot, although the greens are sometimes eaten as well. It is a domesticated form of the wild carrot *Daucus carota*, native to Europe and southwestern Asia. The domestic carrot has been selectively bred for its greatly enlarged and more palatable, less woody-textured edible taproot.

Carrots are one of the ten most economically important vegetable crops in the world (Simon *et al*., 2008). According to FAO for the calendar year 2013, world production of carrots (combined with turnips) was 37.2 million tonnes, with China producing 45% of the world total (16.8 million tonnes). Other major producers were Uzbekistan and Russia (4% of world total each), the United States (3%) and Ukraine (2%). In 2011, the Food and Agriculture Organization of the United Nations (FAO) reported that world production of carrots and turnips were almost 35.658 million tones. Almost half were grown in China. In the year 2009-2010, the area under carrot cultivation was 1,215 hectares, total production of 14,000 metric tons in Bangladesh (BBS, 2010). World production of carrot in 2013 is shown in figure 2.1.

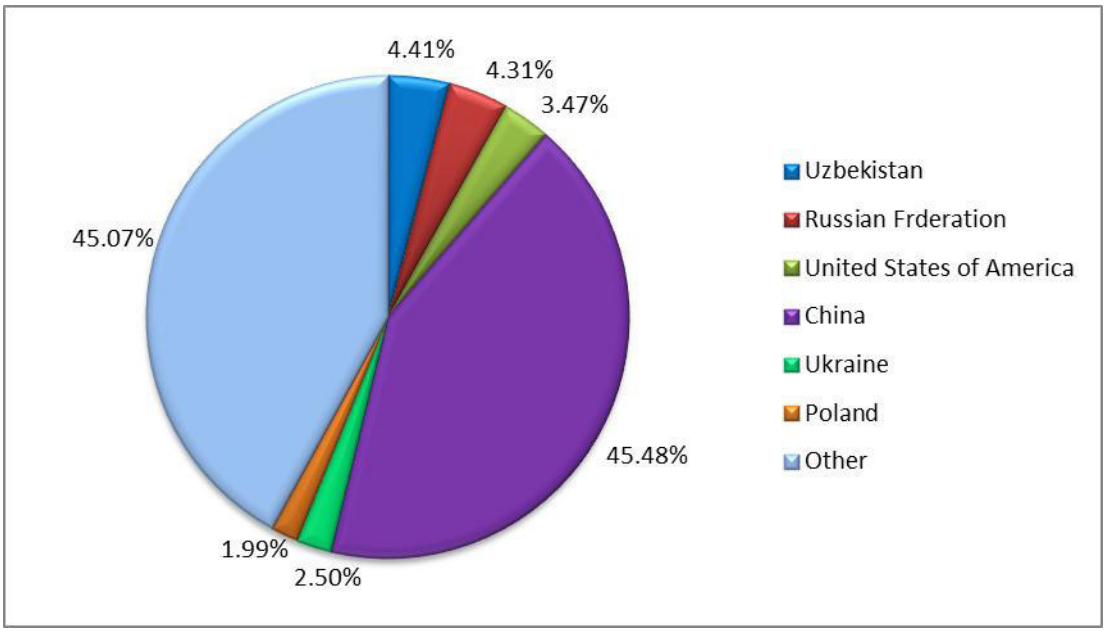


Figure 2.1 Top producers of carrot in 2013 (FAOSTAT, 2013)

2.2 Nutritional value of carrot

Among 39 selectively collected fruits and vegetables carrots have been ranked 10th in nutritional value (Acharya *et al.,* 2008). Carrot contains 88% moisture, 4.7% sugar (free sugars include sucrose, glucose and fructose), 2.6% protein, 1% ash and 0.2% fat (Rubatzky *et al*., 1999). It is a good source of dietary fiber, magnesium, manganese and of the trace mineral molybdenum, rarely found in many vegetables. Carrot dietary fiber comprises mostly cellulose, with smaller proportions of hemicelluloses, lignin and starch (Johnson, 2014). Carrots are also a good source of vitamin K and vitamin B_6 (Rubatzky *et al*., 1999).

Carotenoids and anthocyanins are the major antioxidant pigments found in carrots. The carrot gets its bright orange color from β-carotene, lesser amounts of α-carotene, γ-carotene, lutein and zeaxanthin (Strube *et al.,* 1999). α- and β-carotenes are partly metabolized into vitamin A (Novotny *et al.,* 1995), providing more than 100% of the Daily Value (DV) per 100 g serving of carrots. Red carrot color is due to its high lycopene content (Dias, 2012).

2.3 Health Benefits of Carrots

2.3.1 Antioxidant, Anticarcinogen and Immunoenhancer Benefits

Like many other colored vegetables carrot is a gold mine of antioxidants. Carotenoids, polyphenols and vitamins present in carrot act as antioxidants, anticarcinogens and immunoenhancers. Carotenoids widely distributed in orange carrots are potent antioxidants which can neutralize the effect of free radicals. They have been shown to have inhibition mutagenesis activity contributing to decrease risk of some cancers (Dias, 2012).

Zhang and Hamauzuet (2004) reported that flavonoids and phenolic derivates present in carrot roots play also an important role as antioxidants. They also exert anti-carcinogenic activities, reduce inflammatory insult and modulate immune response (Dias, 2012).

Table 2.1 Nutritional value of raw carrot (per 100 g)

Energy	173 kJ (41 kcal)
Carbohydrates	9.6 g
Sugars	4.7 g
Dietary fiber	2.8 g
Fat	0.24 g
Protein	0.93 g
Vitamins	
Vitamin A equiv.	835 µg
beta-carotene	8285 µg
luteinzeaxanthin	256 µg
Thiamine (B_1)	0.066 mg
Riboflavin (B_2)	0.058 mg
Niacin (B_3)	0.983 mg
Pantothenic acid (B_5)	0.273 mg
Vitamin B_6	0.138 mg
Folate (B_9)	19 µg
Vitamin C	5.9 mg
Vitamin E	0.66 mg
Vitamin K	13.2 µg
Minerals	
Calcium	33 mg
Iron	0.3 mg
Magnesium	12 mg
Manganese	0.143 mg
Phosphorus	35 mg
Potassium	320 mg
Sodium	69 mg
Zinc	0.24 mg
Other constituents	
Fluoride	3.2 µg
Water	88 g

Source: USDA, 2016

2.3.2 Anti-Diabetic, Cholesterol and Cardiovascular Disease Lowering and Anti-Hypertensive Benefits

Coyne *et al.* (2005) demonstrates a significant association between vitamin A-rich carotenoids and diabetes status. According to these investigators higher blood glucose levels, as well as higher fasting levels of insulin, were observed in study participants with lower level of carotenoids.

Carotenoid levels also decreased as the severity of glucose intolerance increased. These findings suggest that carrot and vitamin A-rich carotenoids might help diabetics to manage their temperature.

Dietary fiber transports also a significant amount of polyphenols and carotenoids linked to the fibre matrix though the human gut (Saura-Calixto and Goni, 2006). They confirmed the strong relationship between dietary fiber intake and lower risk of type 2 diabetes (Dias, 2012).

2.3.3 Wound Healing Benefit

Patil *et al*. (2012) report that animals treated with topical cream of ethanolic extract of carrot root, formulated at different concentrations, showed significant decreases in wound area, epithelization period and scar width when compared to control group animals in an excision wound model. Meanwhile, rate of wound contraction significantly increased. Moreover, there were also significant increases in wound tensile strength, hydroxyproline content and protein content in animals treated with the topical cream formulation of ethanolic extract of carrot seeds. The antioxidant and anti-microbial activities of ethanolic extract of carrot root, mainly flavonoids and phenolic derivates, may be involved in this increased curative property. Wound healing effects may also be due to regulation of collagen expression and inhibition of elevated levels of lipid peroxides.

2.4 Methods of consumption and uses

Carrots can be eaten in a variety of ways. Only 3 percent of the β-carotene in raw carrots is released during digestion: this can be improved to 39% by pulping, cooking and adding cooking oil (Martino, 2006). Alternatively they may be chopped and boiled, fried or steamed and cooked in soups and stews as well as baby and pet foods. A well-known dish

is *carrots julienne* (Gisslen, 2010). Together with onion and celery, carrots are one of the primary vegetables used in a *mirepoix* to make various broths (Rubatzky *et al*., 1999).

The greens are edible as a leaf vegetable, but are only occasionally eaten by humans; (Yeager *et al.,* 2008) some sources suggest that the greens contain toxic alkaloids (Brown, 2012 and Burney *et al.,* 2010). When used for this purpose, they are harvested young in high-density plantings, before significant root development and typically used stir-fried or in salads.

In India carrots are used in a variety of ways, as salads or as vegetables added to spicy rice or dal dishes. A popular variation in north India is the Gajar Ka Halwa carrot dessert, which has carrots grated and cooked in milk until the whole mixture is solid, after which nuts and butter are added (Chapman and Pat, 2007). Carrot salads are usually made with grated carrots with a seasoning of mustard seeds and green chillies popped in hot oil. Carrots can also be cut in thin strips and added to rice, can form part of a dish of mixed roast vegetables or can be blended with tamarind to make chutney (Bidlack *et al.,* 2011).

Since the late 1980s, baby carrots or mini-carrots (carrots that have been peeled and cut into uniform cylinders) have been a popular ready-to-eat snack food available in many supermarkets (Shannon and Nomi, 1998). Carrots are puréed and used as baby food, dehydrated to make chips, flakes, and powder, and thinly sliced and deep-fried, like potato chips (Johnson, 2014).

The sweetness of carrots allows the vegetable to be used in some fruit-like roles. Grated carrots are used in carrot cakes, as well as carrot puddings, an English dish thought to have originated in the early 19th century. Carrots can also be used alone or with fruits in jam and preserves. Carrot juice is also widely marketed, especially as a health drink, either stand-alone or blended with fruits and other vegetables (Cunningham and Sally Jean, 2000).

Carrot in powder form can also be used as a food ingredient and dehydrated carrot also use in enrichment of different foods.

2.5 Carrot enriched product

Anil *et al.* (2016) was conducted a study on development and qualitative estimation of high fibre enriched bread fortified with carrot pomace using carrot pomace powder and refined wheat flour in varying ratio of 2.5:97g, 5:95g, 7.5:92.5g and 10:90g, respectively. The carrot pomace was dried at 45° C and then was grinded into powder. During storage there was loss in the amount of moisture, ash, fat, crude fiber, protein as far as physio-chemical parameters were concerned. The study conducted showed that fortification of carrot pomace directly influences the qualitative aspects of prepared bread while the organoleptic study suggested that bread was acceptable for consumption for a period of six days while T_2 having 5g of carrot pomace was desirable for acceptability on most accounts.

Yogesh *et al.* (2015) were reported that possibilities of utilization of carrot pomace dried powder in chicken cutlets prepared from broiler chicken meat. The study was conducted to assess the effect of different levels (0%, 2.5%, 5%, 7.5% and 10%) carrot pomace dried powder incorporation on physico-chemical, textural properties and sensory attributes of chicken cutlets with its control counterpart. Incorporation of different level of carrot pomace dried powder in chicken cutlets significantly ($P<0.05$) increased in moisture content, ash, crude fibre, cooking yield, pH, water holding capacity and beta-carotene. Decreased ($p<0.05$) protein, fat, shrinkage and cholesterol were found with increasing dried carrot powder inclusions.

Jayamanne *et al.* (2014) developed carotene-enriched pasteurized milk drink using cow milk, steamed and blended carrot and sugar. The ash, total solid, fat and protein contents of the developed product were 0.92 %, 21.4 %, 3% and 3.5 %, respectively. The content of β-carotene was significantly ($p<0.05$) higher in the developed product than the commercially available pasteurized milk packets. The shelf-life of the product was 5 days under refrigeration temperatures (4°C). It can be concluded that a carotene-incorporated pasteurized milk product can be produced as a nutritious drink.

Baljeet *et al*. (2014) reported that utilization of carrot pomace powder (CPP) and germinated chickpea flour (GCF) in biscuits was undertaken to upgrade the nutritional quality and assess the acceptability. The spread ratio of the biscuits increased from 6.1 to 8.4 with the increase of CPP and GCF in the blends. With the increase in the concentration of CPP and GCF, there was an increase in protein, ash and crude fiber

contents. The crude fiber content of the biscuits supplemented with 10% CPP and GCF was the highest (3.2%). The biscuits supplemented with CPP and GCF up to 8% level was of acceptable sensory quality.

Dayal B. *et al.* (2013) studied for developing Vitamin A rich low fat cottage cheese using carrot pulp with different concentrations of carrot pulp used 3%, 6%, 9%, 12% and 15%. The nutritional analysis of the cottage cheese was done and it was observed that it contains moisture about 66.57%, ash 2.63%, fat 0.29%, protein 8.05%, calcium 216.6mg, vitamin A 375.8mcg, carbohydrate 6.8g, mineral (%) 2.63%.

Adegunwa *et al.* (2012) were produced noodles from four flour blends of whole wheat, wheat-cassava, wheat-cassava-soy flour and wheat-cassava-carrot flour blends respectively. The total carotenoid content of the dried carrot sample was found to be 28.34 mg/100 g dry weight basis, while the noodle sample containing 10% dried carrot sample (CSC4) had a total carotenoid content of 1.80 mg/100 g dry weight basis. The results suggest that noodles made from the different flour blends can compare favourably with conventional noodles made from wheat flour in quality and that carrot flour can be used for noodle enrichment.

Rashevska and Vasheka (2011) developed butter enriched with carrot powder. They suggested that introduction of additives improves the organoleptic properties of enriched butter and simultaneously improves the performance of the structure and consistency. They also said that due to the introduction of powder in butter the extra space is formed between additive and butter particles. This increases the hardness of the butter and improves its heat resistance and plasticity. This assumption is consistent and is supported by studies of additives' microstructure. It is set that the powders obtained by different drying technologies influence differently the structures' formation of enriched butter. A products' fat phase was studied by differential scanning calorimetry.

Mridula (2011) established b-carotene rich defatted soy flour fortified biscuits were prepared using different levels of carrot powder only, carrot powder with egg, and carrot powder with ascorbic acid, and evaluated for its physical properties, nutritional composition and sensory characteristics. Minimum lightness (L* values) and maximum redness (a* values) was observed in the biscuits samples with ascorbic acid than the other two types of biscuits. With increasing proportion of carrot powder in flour blends, protein content (7.43 to 8.02%) was decreased while ash, crude fibre and b-carotene content were

enhanced. b-carotene content in all three types of biscuits was in the range of 0.56 to 3.72 mg/100 g biscuits. All three types of biscuits were well accepted in sensory evaluation.

Anisa *et al.* (2011) conducted a study to evaluate candy prepared with 3 different combinations of honey and carrot by using 750 g honey + 1000 g carrot (T1), 1000 g honey + 1000 g carrot and 1250 g honey + 1,000 g carrot. T1 was found to be most preferred candy. Further the T1 candy was assessed for overall quality during storage at room temperature (25–30 °C) for 6 months. Candy can be preserved safely for 6 months in both glass and LDPE packaging materials.

Bahadur *et al.* (2006)were conduct a study to explore the possibility of utilization of waste residues (pomace) obtained during carrot juice extraction for the preparation of a value added product viz. carrot based condensed milk product (gazrella, an Indian sweetmeat). The carrot pomace was treated osmotically in two ways: Firstly, dipping in 65°Brix sucrose syrup, secondly, by adding 35% sucrose (dry powder) to the pomace. The product was further dehydrated convectively at 60°C temperature up to 4-5% moisture content (wet basis) and packaged under vacuum in aluminum laminated package (100 gauge). The dehydrated product was stored at ambient temperature (28-42°C) for 6 months and was utilized for preparation of carrot based condensed milk product. After conducting preliminary trials, a new method was adopted for the preparation of carrot based condensed milk product. The product prepared from osmo-convectively dehydrated pomace had moderate to excellent overall acceptability.

2.6 Pretreatment of carrot

Teferra F. Tadesse *et al.* (2015) observed that the best nutrient retentions (5.25% protein db, 2.49% fat db, 2.17% fiber db and 71.94 ppm β-carotene) were recorded for samples treated at 55°C whereas the 5% salt solution resulted in 2.88% fat, 2.46% fiber and 73.89 ppm β-carotene. The highest crude protein (5.68% db) and crude fiber (2.99% db) were recorded for the combination of 55°C with 15% and the highest crude fat (3.20% db) and β-carotene (74.97 ppm) were obtained from the samples subjected to 55°C and 5%. High total ash contents were associated to high levels of osmotic concentrations irrespective of the blanching temperatures. Concerning the sensory acceptance, color, flavor, taste, texture and overall acceptance of samples blanched at 55°C and soaked in 10% solution were most liked. In most cases, the physicochemical, nutritional and sensory acceptance

of the samples treated with 55°C blanching temperature and 5% salt concentration and combination of the two was observed to be superior to other treatment levels.

Muhammad *et al.* (2015) conducted to evaluate the effect of pre-treatments (0.1% KMS, 0.2% KMS, 0.3% KMS and blanching) and drying methods (mechanical drying and solar drying) on the dehydration and rehydration characteristics of carrot. The two drying methods yielded dehydrated products with different dehydration ratio, rehydration ratio, co-efficient of reconstitution and moisture content in both the dehydrated and rehydrated materials.

Raquel *et al.* (2014) found that the different combinations concentration/time of sodium metabishulphite dipping has a similar effect on the chemical properties of the dried carrots. Furthermore, the dried slices of carrots with and without pre-treatment originated products with similar nutritional characteristics. With respect of color, the total difference of color and browning index was similar to the different solutions of sodium metabishulphite. In addition the browning of the dried carrots was, apparently, independent of the pre-treatment. Similarly, the different combinations of pre-treatment had no visible effect on textural parameters and generally the hardness decreased with the pretreatments.

Alam *et al.* (2013) studied on carrot pomace powder and subjected to various blanching pretreatments i.e. water blanching (WB), steam blanching (SB), citric acid blanching (CB) and potassium metabisulphate (KMS) dipping after blanching (WBS). A control sample (untreated, UT) was kept for comparison. The samples were further dried by various drying methods i.e. convective drying (55°C and 65°C), sun drying and solar drying. The 65°C convective dried samples witnessed minimum drying time with higher fiber, total carotenoids, β-carotene content and minimum change in color parameters. Among the blanching pretreatments, the CB pretreatment showed better efficacy in retaining the quality attributes. Overall, the CB pretreatment followed by convective drying at 65°C was found to be the best drying combination for retaining the quality attributes of carrot pomace.

Aktas *et al.* (2007) used to pretreatment methods steam-blanched and then immersed in a sugar solution. In another method sliced vegetables were coated with sugar powder and then steam-blanched. Solid gain and water loss during pretreatment were measured. The isothermal drying experiments were carried out at 303, 313 and 323 K. Sorption

isotherms of dried samples were determined by a standard gravimetric method at 303, 313 and 323 K. Pretreatments reduced the water content of vegetable samples due to osmotic dehydration. Less shrinkage, better color properties and better cell reconstruction properties were observed for samples pretreated with trehalose either with solution or with powder.

Bahadur *et al.* (2006) treated the carrot pomace in two ways: Firstly, dipping in 65°Brix sucrose syrup; secondly, adding 35% sucrose (dry powder) to the pomace. The product was further dehydrated convectively at 60°C temperature up to 4-5% moisture content (wet basis) and packaged under vacuum in aluminum laminated package (100 gauge). The dehydrated product was stored at ambient temperature (28-42°C) for 6 months and was utilized for preparation of carrot based condensed milk product.

Ambadan (1971) found that blanching of carrot shreds in 5% sugar solution prior to dehydration not only imparts an attractive color but improves the organoleptic and keeping quality of the product.

2.7 Drying of carrot

Cruess (1958) has described a process for the dehydration of carrots. The carrots are dried to about 10% moisture and transferred to portable finishing bins to complete dehydration at 44.4 °C. The methods of preparation and improvement in color, taste and flavor of dehydrated carrots have been reported by a number of workers (Feinberg *et al*., 1964; Stephens and McLemore, 1969; Luh and Woodroof, 1982; Mudahar *et al.*, 1992). Freeze drying provides dried product with porous structure and little or no shrinkage, better taste retention and on rehydration the food resembling the original (Mellor and Bell, 1993).

The flavor of freeze dried carrot is better than the air dehydrated products (Kalra *et al*., 1987); however, main disadvantage of freeze drying is its high cost (Krokida and Philippopoulos, 2006). Excellent retention (96–98%) of carotenoids in freeze dried carrots has been noticed (Rodriguez-Amaya, 1997).

High temperature short time (HTST) processing have been used successfully to retard degradation of carotenoids in processed carrots, with highest destruction of carotenoids in conventional canning (121 °C for 30 min) followed by HTST heating at 120 °C for 30 s, 110 °C for 30 s and acidification plus 105 °C heating for 25 s (Chen *et al.*, 1995). Apart from isomerization and oxidation in high carotenoid containing fruits and vegetables,

carotenoid levels increase during processing. In plant tissues, carotenoids exist in *cis* and *trans* forms and during thermal processing some of the *trans* forms are either lost or converted to *cis* and their derivatives, thereby resulting in overall increase of total carotenoids (Chandler and Schwartz, 1998; Dietz *et al*., 1988).

The moisture sorption isotherm studies in carrot revealed that the un-osmosed dehydrated carrot shreds are more hygroscopic as compared to the osmosed dehydrated samples and require a lower relative humidity for safe storage (Singh, 2001). The effect of different drying technologies (hot-air drying, vacuum drying, combination drying (hot-air drying + vacuum drying) suggested that the combination drying technique can keep the carotenoids of carrot well within the short drying time (Zhang-xue *et al.*, 2007). β-Carotene degradation in carrot is comparatively less in vacuum drying and low super heated steam drying as compared to conventional air drying (Suvarnakuta *et al.*, 2005). The degradation of β-carotene is reportedly associated with the development of off-flavours in dehydrated carrots (Ayres *et al*., 1964; Walter *et al*., 1970). The activities of carotene degrading enzymes can be decreased by blanching (Reeve, 1943). Lipoxygenases are the major enzymes involved in carotene degradation (Kalac and Kyzlink, 1980).

2.8 Packaging and storage of carrot

Ayvaz H. (2011) studied the influences of barrier properties of packaging materials and storage conditions on selected quality attributes of carrot samples processed by pressure-assisted thermal processing (PATP). Baby carrots were packaged in three different pouches made of multilayer films (Nylon/EVOH/EVA, Nylon/EVA and MetPET/PE) and processed at 600 MPa and 110 °C for 10 minutes. Processed pouches were stored at 25 and 37 °C and withdrawn over 12 weeks of storage on a periodical basis and analyzed for color, β-carotene, and total mesophilic aerobic count. Oxygen transmission rates (OTR), water vapor transmission rates (WVTR), melting point and enthalpy of fusion of the packages were also evaluated.

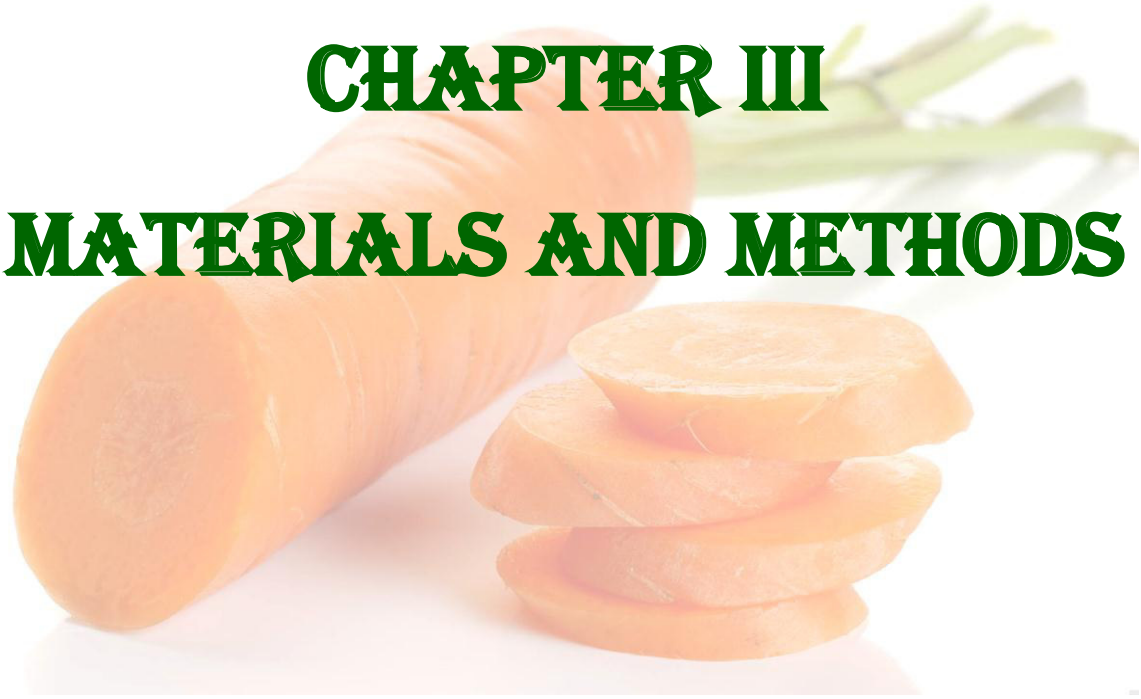
Hidemi *et al*. (1996) monitored physiology and quality of carrot slices, sticks, and shreds stored in air or controlled atmosphere (CA) of 0.5% O2 and 10% CO2 at 0, 5 and 10°C. The respiration of all 3 types of cut tissue was reduced when stored in CA and the reduction was greater with slices or sticks than with shreds. The RQ of sticks and shreds was higher in CA than in air at all temperatures. Ethylene production was less than 0.1 ~1

kg' h' and off-odor was not detected with any of the samples. CA was beneficial in reducing decay, weight loss, pH of sticks and shreds, white discoloration on shreds and microbial growth on sticks. The latter two occurred only at 0 and 5°C.

Sra *et al*. (2014) studied the effect of treatments and packaging on the quality of dried carrot slices during storage. Carrot cultivar 'Nantes' was sliced into 4.5 mm thick slices which were blanched in water at 95 °C for 4 min followed by dipping in 6% potassium metabisulphite (KMS) solution for 40 min and 350 ppm potassium sorbate solution for 10 min prior to two stage phase drying i.e. at 90 ± 5 °C for 2 h and further drying at 60 ± 5 °C for 7 h in a cross-flow hot air cabinet dryer. The dried carrot slices were packed in 50 g packages of aluminium foil laminate (AFL) (polyethylene, aluminium foil and polyester) and high density polyethylene (HDPE) pouches having 32.5 µm and 56.0 µm thickness respectively and stored under ambient conditions i.e.18.5–29.1 °C temperature and 44.4–60.4% relative humidity for 6 months.

Kamiloglu *et al*. (2014) monitor the stability of total phenolics, antioxidant capacity and phenolic acids in black carrot jams and marmalades after processing, storage at 25°C and 4 °C and in vitro gastrointestinal digestion. Total phenolic content and antioxidant capacity were determined using spectrophotometric methods, whereas phenolic acids were identified using HPLC-PDA. Jam and marmalade processing significantly decreased total phenolics (89.2-90.5%), antioxidant capacity (83.3-91.3%) and phenolic acids (49.5-96.7%) ($p < 0.05$).

Zoran *et al*. (2013) studies to examine differences between postharvest treatments, either washed (hot water, H2O2 and Na2OCl) or non-washed (control) carrot roots and the effect of different storage conditions, (0°C and > 95% RH) or (0-2°C and < 90% RH) on the compositional changes. Losses of mass, β-carotene and vitamin C in carrot taproot were monitored during 160 days of cold storage (in both cold room) plus 20 days at 20°C (market simulation).



CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 Materials

The fresh mature carrots (Figure 3.1) used in this study were collected from local market (Bahadur bazaar, Dinajpur). Polyethylene bags, aluminum foil paper and other reagents were purchased from local market. Distilled water was used for all experimental works. All the reagents were of analytical grade.

Figure 3.1 Fresh carrots

3.2 Preparation of sample

After collecting the raw carrot, damaged and immature carrots were sorted out. The sorted carrots were washed with tap water to remove dirt and soil. Then, carrots were cut into cubes (Figure 3.2) with thickness of 0.3-0.5cm by using stainless steel knives.

Figure 3.2 Cubes of carrot

3.3 Methods

3.3.1 Pretreatment of carrot

The carrot cubes were then blanched at 80±2º C in previously prepared chemical solution for 3 minutes in a water bath. Then the blanched cubes were cooled in ice water (5±2ºC). Based on similar previous research (Muhammad *et al*. 2015; Alam *et al.* 2013; Ghavidel and Davoodi, 2009) the selected chemical solutions were as follows:

a) 1% $CaCl_2$ solution

b) 0.2% of potassium metabisulphite solution

c) 1% $CaCl_2$ and 0.2% of potassium metabisulphite mixture

d) Without chemical (only water).

e) Untreated (without blanched as control)

For the above pretreatment works about 500 ml of pretreatment solution was used for each 500gm carrot cubes.

3.3.2 Preparation of carrot powder

Carrot powder was prepared by following the method as described by Rao *et al.* (2011) and Mozumder *et al.* (2012). The pretreated carrot cubes were dried in the cabinet drier (Model- 136-12, Seoul, Korea). The drier consist of a chamber in which trays of products were placed. The cubes were spreaded on stainless steel trays (Figure 3.3) and dried at (60±2)^{o}C temperatures for 18 hours. Then, the dried cubes were ground into powder by using a blender (Jaipan CM/L-7360065, Japan). After that, powder was sieved using stainless steel sieve (Sieve no.MIC-300).

Figure 3.3 Carrot cubes before and after dry

3.3.3 Packaging and storage

Carrot powder was packed in low density polyethylene bags, density range of 0.910–0.940 g/cm^3 (Figure 3.4). The obtained powder was sealed and store at freezing (-10±2ºC), refrigeration (4±2ºC) and room temperature (22±2ºC) until used.

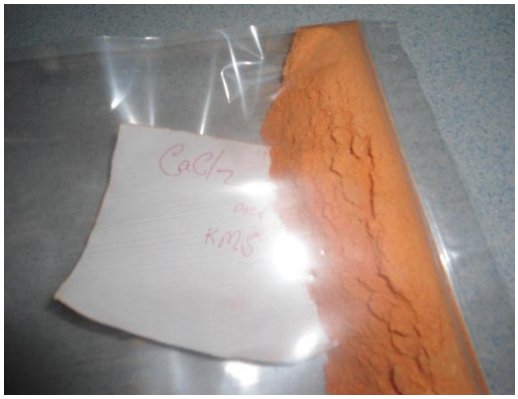


Figure 3.4 Carrot powder in low density polyethylene bags

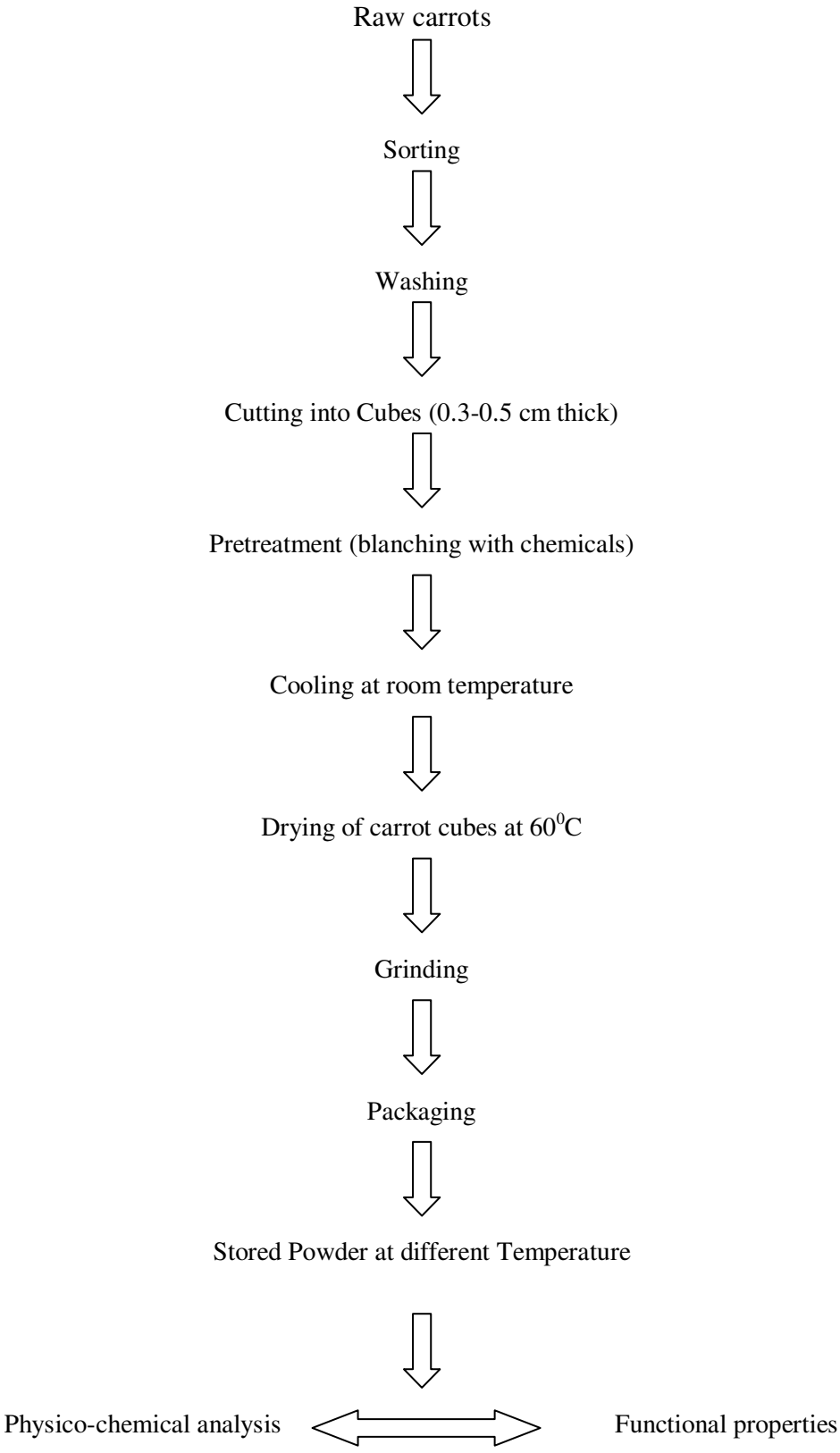


Figure 3.5 Flowchart for production and analysis of carrot powder

3.3.4 Assessment of physico-chemical analysis

3.3.4.1 Determination of moisture content

AOAC method 7.045 (2000) was used to determine the moisture content of carrot powder. 3g powder was taken in a clean, dry and pre-weighted crucible. Then the powder was transferred to oven and dried at 105ºC for 24 hours. After that it was cooled at desiccator and weighed. Moisture content was calculated by following formula:

$$\% \text{ Moisture} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1 = weight of sample with crucible

W_2 = weight of dried sample with crucible

W = weight of sample

3.3.4.2 Determination of fat content

To determine the fat content of carrot powder the AOAC method 7.045 (2000) was used with some modification. Carrot powder of 3g was taken into the thimble. Then the thimble was attached to the Soxhlet apparatus which was attached with a round bottom flask containing 250 ml petroleum ether. The fat was extracted for 6 hours. After that petroleum ether was evaporated at 105ºC until the flask completely dried. Fat content was calculated by following formula:

$$\% \text{ Fat} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1 = weight of evaporated flask with fat

W_2 = weight of empty flask

W = weight of sample

3.3.4.3 Determination of ash content

Total ash content of carrot powder was measured by AOAC method 14.006 (2000). Sample (3gm) was weighed and transferred into a clean, dry and pre-weighted crucible. Then the crucible was kept into muffle furnace at 550ºC for 6 hours. Turn off muffle furnace and wait to open it until the temperature has dropped to at least 250° C, preferably lower. Opened the door carefully and cooled ignited powder at desiccator and weighed. The ash content was calculated by the following formula:

$$\% \text{ Ash} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1 = weight of ash with crucible

W_2 = weight of empty crucible

W = weight of sample

3.3.4.4 Determination of protein content

Protein content in the sample was measured spectrophotometrically according to Bradford method (Bradford, 1976) with little modification. Sample (0.5g) was taken in a beaker then 10 mL of distilled water was added to it. Then the sample was stirred with magnetic stirrer and filter with a filter paper. Then 500µL sample (after filtration) was taken into a falcon tube and diluted to 4500µL distilled water. Then 5mL of Bradford reagent was added and mixed by vortex (KMC-1300V, Korea) for few minutes. The concentration of protein in the solution was determined from the absorbance at 595 nm (T60 U, PG instrument, United Kingdom). Protein content was calculated on the basis of calibration curves of bovine serum albumin and expressed as percentage.

3.3.4.5 Determination of fiber content

The carrot powder sample was taken for crude fiber analysis by adopting the procedure mentioned in AACC (2000) Method No. 32- 10. 5g sample was used to determine crude fiber of carrot powder. Samples were boiled for 30 minutes in the presence of 1.25% H_2SO_4 and then filtered and washed. Then the sample was again boiled in 1.25% NaOH for 30minutes and then filtered and washed. The resultant residue was dried at 110ºC for

2 hours and weighed. The dried residue was ignited at 550±15ºC, cooled and reweighed. The crude fiber was calculated according to following expression:

$$\% \text{ Fiber} = \frac{\text{Loss in weight on ignition}}{\text{weight of sample}} \times 100$$

3.3.4.6 Determination of beta-carotene content

ß-carotene content of carrot powder was determined by a slightly modified method described by Nagata and Yamashita (1992). At first prepared a mixture of acetone-hexane with a proportion of 4:6. Then 1g sample was homogenized with 10 ml of acetone-hexane mixture. After that centrifuged the solution at 3600rpm for 10 minutes and collected the supernatant. A little amount of supernatant was taken in a cuvette of spectrophotometer and absorbance of the mixture was measured at 453, 505 and 663 nm. ß-carotene content was calculated using the following equation:

ß-carotene (mg/100mg) = $0.216A_{663} - 0.304A_{505} + 0.452A_{453}$

ß-carotene (µg/100g) = ß-carotene (mg/100mg) ×1000

3.3.4.7 Determination of color

Color of the carrot powder was evaluated by a color measurement spectrophotometer (Minolta Camera, Tokyo, Japan) set for Hunter L^*(lightness), a^* (redness) and b^* (yellowness) values. L^* is measured on scale of 0=black to 100=white, a^* measures red to green with +a being red, and -a being green, and b^* measures yellow to blue with +b being yellow and -b being blue. The results of the Hunter L^*, a^* and b^* values were averaged from 2 replications.

3.4.5 Evaluation of functional properties

3.4.5.1 Determination of water absorption index (WAI)

The WAI content was measured by the method of Asaduzzaman *et al*. (2013) with some modification. Carrot powder (0.40g) was suspended with 10 ml of water into a 15 ml tired centrifuge tube. Then the mixture was centrifuged for 20 min at 3500 rpm and the supernatant was poured carefully into a dish. The residue was weighed. Water absorption index was determined by following formula:

$$\text{WAI}(g/g) = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1 = weight of tube with residue

W_2 = weight of the tube

W = weight of sample

3.4.5.2 Determination of rehydration ratio

The rehydration test was conducted as recommended by McMinn and Magee (1997) and Prabhanjan *et al*. (1995). One gram sample of the dried carrot powder was added to 30 ml of distilled water in a beaker. The beaker was then placed on a hot plate and covered with a watch glass. It takes approximately 3 min to bring the water to boiling point and then kept for 5 min. At the end of the rehydration period, the sample was transferred to a Buchner funnel, covered with No. 4 Whatman filter paper and the excess water removed by applying a slight vacuum. The sample was then removed and weighed. The data was calculated from the following formula:

$$\text{RR} = \frac{M_{rh}}{M_{dh}}$$

Where, M_{rh} is the mass of the rehydrated sample (kg) and M_{dh} is the mass of the sample dried for rehydrated test (kg).

3.4.5.3 Determination of swelling capacity

The swelling capacity of carrot powder was determined by the method of Okaka and Potter (1977) with some modifications. The sample filled up to 10 ml mark in a 100 ml graduated cylinder. Then, added water to adjusted total volume to 50 ml of cylinder. Then top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. After 2 min later the suspension was inverted again and allowed to stand for further 30 min. The volume occupied by the sample was taken after 30 min.

3.4.5.4 Determination of degree of caking

Degree of caking of carrot powder was estimated by the method given by Pisecky (1986), with slight modifications. 5g powder was weighed and transferred onto a sieve. Then the sieve was shacked for 5min.Weighted the powder remaining in the sieve.

The per cent degree of caking was calculated by using the following formula:

$$DC = \frac{a}{b} \times 100$$

Where, *b* is the weight (in gm) of the powder used for sieving and *a* is the weight (in gm) of the powder left on the sieve after sieving.

3.4.5.5 Determination of bulk density

Jinapong *et al.* (2008) method was used to determine bulk density of carrot powder. 1 gm of sample was weighed in a graduated cylinder. Gently tapped the base of the cylinder and read off the volume of sample in ml. Determine bulk density according to the formula:

$$\text{Bulk Density}\,(\text{gm/ml}) = \frac{m}{V}$$

Here,

m = mass of sample (gm)

V = volume of sample (ml)

3.4.5.6 Determination of solubility

The solubility of the carrot powder was determined according to the Cano-Chauca *et al.* (2005) with some modification. Carrot powder (1g) in 100 ml of distilled water homogenized by a magnetic stirred for 5 min at high speed. Then the solution was centrifuged at 3000 rpm for 10 min and the supernatant was collected. An aliquot of 25 ml of the supernatant was transferred to pre-weighed petridishes and oven-dried at 105°C overnight. The solubility was calculated by weight difference and expressed as percentage.

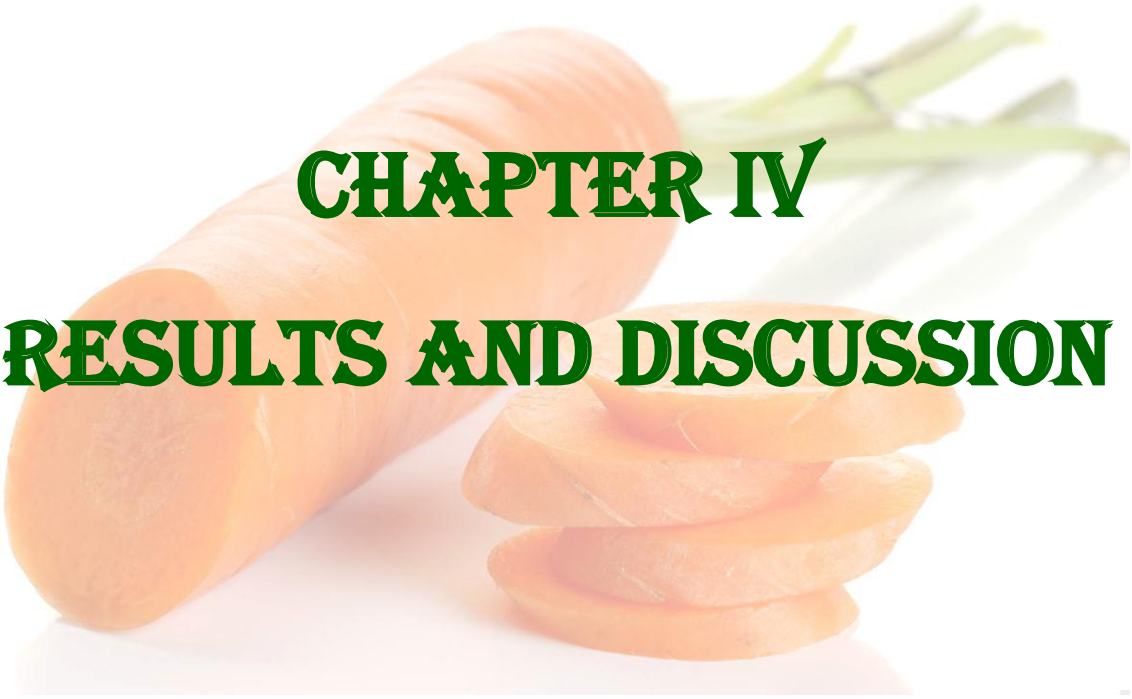
3.4 Determination of percent loss

Percent loss of beta-carotene and color (L^*, a^* and b^*) were calculated by the following formula:

$$\text{Percent loss} = \frac{\text{Initial value} - \text{final value}}{\text{Initial value}} \times 100$$

3.5 Statistical analysis

Each experiment was done in duplicate. The statistical software package SAS 9.3 version was employed for the analysis of variance and Duncan's Multiple Range Test for physico-chemical and functional properties test. Two factor (pretreatment and storage temperature) completely randomized design (CRD) was employed for analysis of the obtained data $P \leq 0.05$ was considered as a level of significance.



CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Effect of pretreatments and storage temperatures on physico-chemical properties

Table 4.1 and 4.3 show that initially only pretreatments have significant effect (at $p \leq 0.001$) on physico-chemical properties of prepared carrot powder. Storage temperature noted to show no significant ($p \leq 0.001$) difference as it was initial day of storage. But, storage temperature produced a statistically significant ($p \leq 0.001$) difference along with pretreatment on the physico-chemical properties of carrot powder at 30 and 60 days of storage. There was also a significant ($p \leq 0.001$) effect of pretreatment and storage temperature interaction on the physico-chemical properties of the carrot powder storage. As per the objectives of the study, interaction effect was not further evaluated.

4.1.1 Moisture content

From table 4.2, the initial moisture content (7.90%) of carrot powder for blanching with KMS treated sample was found to be higher compared to that of moisture content (6.32%) in water blanched sample. The results obtained in the present study for moisture were slightly higher than that of Pua *et al.* (2007), who reported that moisture content range 5.71 – 8.22% of other fruit powders such as jackfruit but consistent with Akubor and John (2012), who reported that moisture content of oven dried carrot flour is 7% and sundried carrot flour is 8%.

After 30 days of storage, the KMS treated sample presented the highest moisture content (8.81%) whereas the lowest moisture content (7.67%) was found in case of water blanched sample. The highest moisture content (8.80%) was noticed in carrot powder stored at ambient temperature and the lowest moisture content (7.99%) was noted in sample stored at freezing storage temperature.

In the study period of 60 days, maximum moisture content (10.26%) was obtained from untreated sample i.e. control sample and minimum moisture content (9.22%) was obtained from KMS blanched sample. The trend of storage temperature on moisture absorbsion was similar as was 30 days. In terms of moisture content, carrot powder treated with KMS and stored at freezing temperature gave better result.

Table 4.1 Effect of pretreatments, storage temperatures and their interaction on moisture, fat and ash content of carrot powder

Quality Parameters										
		Moisture content			Fat content			Ash content		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Factors	Pretreatment	1278.46***	576.54***	866.40***	1643.37***	1384.66***	1195.74***	9208.94***	2603.02***	949.32***
	Storage temperature	0ns	749.36***	5087.47***	0 ns	658.54***	1217.90***	0 ns	636.78***	978.13***
	Pretreatment *Storage temperature	0ns	2.36ns	10.50***	0 ns	21.95***	35.47***	0 ns	27.59***	44.50***
Coefficient of variance (CV)%		0.56	0.55	0.33	1.15	1.11	1.13	0.48	0.77	0.94

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

Table 4.2 Change in physico-chemical properties with different pretreatments and storage temperatures of carrot powder

Factors	Quality Parameter	Moisture content (%, wb)			Fat content (%, wb)			Ash content (%, wb)			Protein content (%, wb)			Fiber content (%, wb)		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Pretreatments	$CaCl_2$	7.44^{b}	8.71^{b}	9.97^{b}	3.22^{d}	2.50^{c}	2.02^{c}	5.31^{c}	4.44^{c}	3.80^{c}	**7.86^{a}**	4.23^{b}	2.20^{b}	13.94^{d}	7.01^{c}	3.41^{d}
	KMS	**7.90^{a}**	**8.81^{a}**	9.22^{d}	3.43^{c}	2.75^{b}	2.24^{b}	5.24^{d}	4.65^{b}	4.12^{b}	6.56^{b}	**4.59^{a}**	**2.89^{a}**	**18.34^{a}**	**11.06^{a}**	**6.87^{a}**
	$CaCl_2$ + KMS	7.03^{d}	8.30^{d}	9.99^{b}	**3.81^{a}**	**2.97^{a}**	**2.57^{a}**	**7.57^{a}**	**5.99^{a}**	**4.62^{a}**	5.50^{c}	2.92^{c}	1.43^{c}	15.47^{c}	8.30^{b}	4.32^{c}
	Water	6.32^{e}	7.67^{e}	9.74^{c}	3.57^{b}	2.71^{b}	1.83^{d}	4.85^{e}	4.06^{e}	3.54^{d}	4.33^{d}	2.31^{d}	0.98^{d}	16.92^{b}	8.30^{b}	4.39^{b}
	Control	7.17^{c}	8.56^{c}	**10.26^{a}**	2.44^{e}	1.85^{d}	1.55^{e}	5.58^{b}	4.32^{d}	3.50^{d}	3.84^{e}	1.52^{e}	0.82^{e}	6.66e	3.01^{d}	0.86^{e}
Storage temperatures	A	**7.17^{a}**	**8.80^{a}**	**10.56^{a}**	**3.29^{a}**	2.34^{c}	1.26^{c}	**5.71^{a}**	4.42^{c}	3.55^{c}	**5.62^{a}**	2.20^{c}	0.93^{c}	**14.26^{a}**	4.47^{c}	1.62^{c}
	R	**7.17^{a}**	8.44^{b}	9.84^{b}	**3.29^{a}**	2.52^{b}	1.72^{b}	**5.71^{a}**	4.66^{b}	3.93^{b}	**5.62^{a}**	3.02^{b}	1.60^{b}	**14.26^{a}**	7.59^{b}	3.46^{b}
	F	**7.17^{a}**	7.99^{c}	9.10^{c}	**3.29^{a}**	**2.80^{a}**	**1.91^{a}**	**5.71^{a}**	**4.99^{a}**	**4.28^{a}**	**5.62^{a}**	**4.11^{a}**	**2.45^{a}**	**14.26^{a}**	**10.54^{a}**	**6.83^{a}**

a-e means followed by different superscript in each column are significantly different among pretreatment ($CaCl_2$- Control) and a-c means followed by different superscript in each column are significantly different among storage temperature (A-F) at ($p \leq 0.001$).
A = Ambient Temperature, R = Refrigeration Temperature, F = Freezing Temperature

An increase was observed in the moisture content during 60 days of storage; this might be due to the hygroscopic nature of the dried product. The moisture content of carrot powder stored at freezing was significantly lower ($p \leq 0.001$) than the powder stored at refrigeration and ambient; it may be due to relative humidity and respiration rate of ambient to freezing. This shows that freezing provided better barrier to moisture transfer than ambient. Hymavathi and Khader (2005) reported that increase in moisture content upon storage attributed to the migration of water vapour from the storage environment into the packaging material.

4.1.2 Fat content

From Table 4.2 it can be seen that the initial fat content (3.81%) was higher for the carrot powder which was blanched by combine $CaCl_2$ and KMS and the lowest value (2.44%) corresponded to the sample that received no blanching treatment. These values were higher from Teferra F. Tadesse *et al.* (2015), who found fat content (1.45-2.88%) in case of carrot slices.

Decrease in fat content was observed throughout the storage periods. In the study of 30 days storage, combine $CaCl_2$ and KMS treated sample maintained higher fat content (2.97%) and control sample showed fat content (1.85%) which was significantly lower than the other treatments. Among the storage temperature, sample stored at freezing temperature showed significantly ($p \leq 0.001$) higher fat content in comparison to sample stored at refrigeration and ambient temperature.

Even after 60 days of storage, combine $CaCl_2$ and KMS treated sample was noticed to have higher fat content (2.57%) and control sample showed lower fat content (1.55%). The trend of fat content decreasing rate in sample was lower at freezing than refrigeration and ambient. To maintain higher fat retention, combine $CaCl_2$ and KMS blanching pretreatment and freezing storage temperature was best suited.

4.1.3 Ash content

From table 4.2 it is clear that ash content of carrot powder was generally decreased with increase in the storage period. The initial ash content (7.57%) was observed to be the highest in case of sample treated with combine $CaCl_2$ and KMS blanching whereas the lowest ash level (4.85%) was observed in case of water blanched sample. These values were lower than Teferra F. Tadesse *et al.* (2015), who reported ash content 9.45-10.90%

(db) for solar dried carrot slices and similar with Raqual *et al.* (2014), who found ash content 4.70-7.96 g/100g (db) for oven dried carrot. The increase in ash content is possibly due to calcium and potassium in the solution that might have diffused into the carrot as the water migrates out in blanching.

After 30 days of storage, blanching with combine $CaCl_2$ and KMS sample retained the highest ash content (5.99%) and the lowest value (4.06%) recorded for the sample that was treated by blanching with water. It was also observed that ash content (4.99%) was higher for sample stored at freezing temperature than ash content (4.66% and 4.42%) for samples stored at refrigeration and ambient temperatures respectively.

At 60 days, the highest and lowest ash content (4.62% and 3.50%) were in sample blanched with combine $CaCl_2$ and KMS solution and water respectively. Maximum ash content (4.28%) retention was observed for the sample stored at freezing temperature while the minimum ash content (3.55%) at ambient stored sample. In case of higher ash content, carrot powder treated with combine $CaCl_2$ and KMS blanching and stored at freezing temperature was superior to other pretreatment and storage temperature.

4.1.4 Protein content

Table 4.2 shows on the initial day of storage, the $CaCl_2$ blanching sample was witnessed significantly higher protein content (7.86%) compared to that of control sample which was witnessed significantly lower protein content (3.84%). Similar results were found by Raquel *et al*. (2014) for dehydrated carrot slices (4.36-7.66 g/100g) but higher than Teferra F. Tadesse *et al.* (2015), who found protein content (3.75-5.25%db) for solar dried carrot slices.

During storage of 30 days, the protein content decreased for carrot powder. The decline in protein content (60.42%) was recorded higher for untreated control sample than treated samples and minimum protein declination (39.29%) occurred in KMS treated sample. The highest protein content (4.11%) was observed in sample stored at freezing temperature and the least (2.20%) was in case of ambient stored sample.

But at 60 days of storage, protein content (0.82%) was found to be very low in control sample and sample subjected to KMS blanching showed greater protein content (2.89%). Storage temperatures also have a significant ($p \leq 0.001$) effect on protein content of carrot powder storage. Carrot powder stored at freezing storage temperature showed higher

Table 4.3 Effect of pretreatments, storage temperatures and their interaction on protein and fiber content of carrot powder

Quality Parameters							
		Protein content			Fiber content		
		0 days	30 days	60 days	0 days	30 days	60 days
Factors	Pretreatment	19172.2***	844.64***	2 170.88***	37266.9***	89876.1***	39659.5***
	Storage temperature	0 ns	773.18***	2762.38***	0 ns	160648***	98722.7***
	Pretreatment*Storage temperature	0 ns	27.43***	132.21***	0 ns	3837.51***	4377.77***
Coefficient of variance (CV)%		0.63	3.5	2.75	0.41	0.32	0.67

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

retention of protein content. Regarding the protein content of carrot powder, KMS pretreatment and freezing temperature was the best pretreatment and storage temperature to retain higher protein content.

4.1.5 Fiber content

Table 4.2 explains that the initial fiber content of carrot powder was found to vary from 18.34% to 6.66%. The fiber content obtained in present study was close to Alam *et al.* (2013), for carrot pomace powder (7 to 19%). Higher values were found for solar dried carrot slices (1.11- 2.46% db, Raquel *et al*., 2014) and oven dried carrot slices (4.50-6.02g/100g db, Teferra F. Tadesse *et al.,* 2015).

Although a reduction in fiber content was observed throughout the storage period, the carrot powder treated with KMS blanching showed higher fiber content (11.06%) after 30 days of storage. Control showed lower fiber content (3.01%) throughout the storage periods. Storage of sample at freezing temperature showed greater fiber content (10.54%) compared to that of sample stored at refrigeration and ambient temperature.

Even after 60 days of storage, fiber content (6.87%) was higher in KMS treated sample while the lower (0.86%) in control sample. Sample stored at freezing temperature showed higher fiber content (6.83%) and sample stored at ambient temperature showed lower fiber content (1.62%). Concerning the fiber content, KMS pretreatment and freezing storage temperature was best suited pretreatment and storage temperature for carrot powder.

Arthey and Ashurt (2001) reported that blanched samples have higher values than the boiled samples because of wet hydrothermal processing as wet processing such as cooking and blanching may change some fiber properties, for example, the amount of soluble fiber in fruit may increase by partial breakdown of pectin.

4.1.6 Influence of pretreatments and storage temperatures on beta-carotene content

Statistical analysis (Table 4.4) explains that initially there was a significant ($p \leq 0.001$) effect of blanching pretreatments on beta-carotene content of carrot powder. At 30 and 60 days of the study pretreatment and storage temperature both significantly ($p \leq 0.001$) affect

the beta-carotene content of carrot powder. Though there was a significant effect of pretreatment and storage temperature interactions, it was avoided as per objective.

Table 4.5 explains that on the initial day of storage, retention of beta-carotene (2737.03µg/100 g) was recorded higher in case of sample treated with KMS blanching whereas sample treated with combination of $CaCl_2$ and KMS retained lower beta-carotene (2257.45µg/100 g). Beta-carotene content of present study was higher to that of Alam *et al*. (2013), who reported that beta-carotene content of carrot pomace powder range from 186.01 to 633.57 µg/100g. The highest value was obtained from KMS treated sample that contrasted with Ghavidel and Davoodi (2009), who reported that combine $CaCl_2$ and KMS more protective on lycopene degradation in tomato powder.

At 30 days of storage, the β-carotene content (1980.51µg/100 g) was found to be the highest in KMS pretreated powder while the lowest value (1119.26µg/100 g) was found in $CaCl_2$ pretreated carrot powder. Among the storage temperature, retention of β-carotene (2010.21µg/100 g) was higher in case of sample stored at freezing temperature than that of β-carotene 1557.43µg/100 g and 1143.94µg/100 g in sample stored at refrigeration and ambient temperature respectively. The percent loss (53.4%) of beta-carotene was higher in ambient stored sample than percent loss (18.11%) in freezing stored sample (figure 4.1).

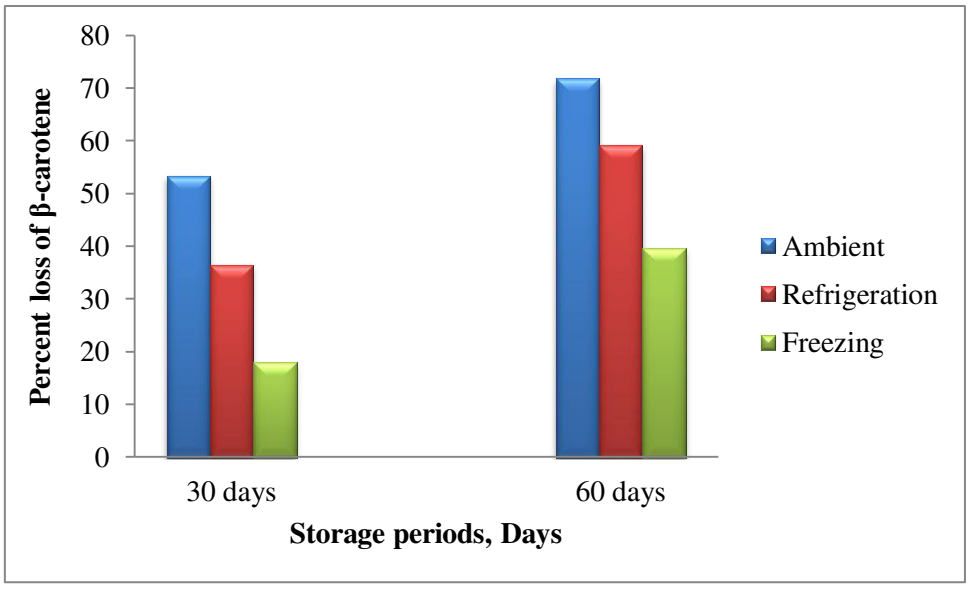


Figure 4.1 Percent loss of beta-carotene of carrot powder

Even after 60 days, sample blanched with KMS recorded higher β-carotene retention (1475.59µg/100 g) and was lower (599.83µg/100 g) in $CaCl_2$ treated sample. Among the stored sample, freezing stored sample was scored higher β-carotene (1481.03µg/100 g) than that of ambient and refrigeration stored sample. Beta-carotene is susceptible to oxidative loss caused by heat and light which are responsible for the losses during storage (Dutta D. *et al*., 2006). They also reported that β-carotene content of dried sample depends on temperature, storage period and storage temperature. In case of beta-carotene retention, KMS pretreatment and freezing temperature was the suitable pretreatment and storage temperature.

Tomkins *et al.* (1944) reported that the proportion of β-carotene oxidized during storage was higher at 8.2% moisture than at 5.4% moisture. Similar reason may be the causes for losses of β-carotene in the present study during storage. The beta-carotene content degraded significantly during storage. Shi and Maguer (2000) also reported that oxidation, isomerisation and other chemical changes during processing and storage are responsible for beta-carotene degradation.

Table 4.4 Effect of pretreatments, storage temperatures and their interaction on beta-carotene of carrot powder

Quality Parameters				
		Beta-carotene		
		0 days	30 days	60 days
Factors	Pretreatment	440.15***	109504***	318502***
	Storage temperature	0.00 ns	265832***	594154***
	Pretreatment*Storage temperature	0.00ns	2019.01***	5016.39***
Coefficient of variance (CV)%		1.08	0.17	0.15

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

Table 4.5 Change in beta-carotene with different pretreatments and storage temperatures of carrot powder

Factors \ Quality Parameter		Beta-carotene(µg/100g)		
		0 days	30 days	60 days
Pretreatments	$CaCl_2$	2287.15^{d}	1119.26^{e}	599.83^{e}
	KMS	**2737.03^{a}**	**1980.51^{a}**	**1475.59^{a}**
	$CaCl_2$ + KMS	2257.45^{d}	1295.93^{d}	758.62^{d}
	Water	2661.32^{b}	1824.733^{b}	1356.24^{b}
	Control	2330.58^{c}	1632.203^{c}	1101.12^{c}
Storage temperatures	Ambient	**2454.70^{a}**	1143.94^{c}	692.04^{c}
	Refrigeration	**2454.70^{a}**	1557.43^{b}	1001.76^{b}
	Freezing	**2454.70^{a}**	**2010.21^{a}**	**1481.03^{a}**

a-e means followed by different superscript in each column are significantly different among pretreatment ($CaCl_2$-Control) and a-c means followed by different superscript in each column are significantly different among storage temperature (ambient-freezing) at ($p \leq 0.001$).

4.1.7 Color

From Table 4.6 it is clear that only pretreatments have significant effect at $p \leq 0.01$ on L^* value and significant effect at $p \leq 0.05$ a^* and b^* color value at 0 day. But pretreatment, storage temperature and pretreatment storage temperature interaction significantly ($p \leq 0.001$) influenced the color properties (L^*, a^* and b^*) values of carrot powder at 30 and 60 days of storage.

The results of the L^*, a^*, b^* values for carrot powder were given in Table 4.7. Figure 4.3 also indicates the notable color difference among the pretreated carrots powder and storage temperature.

4.1.7.1 L^* value

Table 4.7 shows that the color brightness value, L^* (40.19) of the sample blanched with $CaCl_2$ was found to be significantly ($p \leq 0.01$) higher from other four samples. Raquel *et al*. (2014) was found L^* value (58.26-64.69) in dried carrot which was higher than the results of present study.

The L^* value of carrot powder increased (i.e. turn into white) throughout the storage periods. At 30 days, the carrot powder pretreated with KMS were found to have the lowest L^* value (39.04) followed by water blanched sample (L^* value 40.12). The highest L^* value (50.99) was found in $CaCl_2$ treated sample. Sample stored at the freezing storage temperature recorded L^* value (41.12) that was significantly lower than 48.79 which recorded at ambient temperature. After 60 days of storage L^* value of all sample was increased gradually and there was a significant ($p \leq 0.001$) difference among the entire sample. The highest L^* value (54.98) observed in case of sample treated with combine $CaCl_2$ and KMS and the least (42.38) in case of KMS treated sample.

Sample stored at freezing recorded the lowest L* value (43.16) compared to the highest L^* value (54.31) in case of sample stored at ambient. Maximum percent gain (42.63) of L^* value was occurred in ambient stored sample compared to that of percent gain (13.37) of L^* value in freezing stored sample (figure 4.2).

It is evident that KMS pre-treatment had a beneficial effect on the color of carrot powder. Atkinson and Strachan (1962) reported that KMS is widely used for inhibiting browning in foods.

4.1.7.2 a^* value

If pretreatments were checked from table 4.7 it can be seen that a^* values for all samples except $CaCl_2$ were measured as the similar values compared to that of control. The a^* color value (29.44) was found to be slight higher in case of water blanched and $CaCl_2$ blanched carrot powder showed significantly ($p \leq 0.05$) lower value (27.51). Similar results were obtained by Raquel *et al*. (2014) for dried carrot where the a^* value range from 24.86 to 32.54.

Table 4.7 again indicates that a^* color value declined during progressive storage which represents degree of redness in the product. During subsequent storage the typical red color of carrot powder gradually changes to brick-red and then brown. This phenomenon which is known as non-enzymatic browning (NEB) or Millard reaction produces dark pigments and destroys the natural color of products (Poretta and Sandei, 1990).

Table 4.6 Effect of pretreatments, storage temperatures and their interaction on color of carrot powder

Color										
		L^* value			a^* value			b^* value		
		0 days	30 days	60 days	0 Days	30 days	60 days	0 days	30 days	60 days
Factors	Pretreatment	5.81^{**}	140.08^{***}	360.21^{***}	3.45^{*}	227.54^{***}	471.78^{***}	3.89^{*}	99.95^{***}	235.41^{***}
	Storage temperature	0^{ns}	171.80^{***}	585.58^{***}	0^{ns}	282.38^{***}	992.15^{***}	0^{ns}	191.45^{***}	342.75^{***}
	Pretreatment*Storage temperature	0^{ns}	20.53^{***}	34.57^{***}	0^{ns}	23.09^{***}	35.75^{***}	0^{ns}	15.22^{***}	6.17^{**}
Coefficient of variance (CV)%		3.50	2.35	1.51	3.38	4.39	3.47	2.96	3.67	2.67

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

Table 4.7 Change in color with different pretreatments and storage temperatures of carrot powder

Factors \ Quality Parameters		Color								
		L *			a *			b *		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Pretreatments	$CaCl_2$	**40.19^{a}**	**50.99a**	53.92^{b}	27.51^{b}	14.15^{d}	10.09^{d}	32.29^{a}	21.84^{d}	18.59^{d}
	KMS	37.91^{b}	39.04^{d}	42.38^{e}	**28.99^{a}**	**24.21^{a}**	**18.55^{a}**	**32.56^{a}**	**28.86^{a}**	**25.71^{a}**
	$CaCl_2$ + KMS	37.02^{b}	47.84^{b}	**54.98^{a}**	28.76^{a}	12.43^{e}	8.54^{e}	33.07^{a}	19.93^{e}	16.82^{e}
	Water	36.97^{b}	40.12^{d}	44.79^{d}	29.44^{a}	20.32^{b}	16.11^{b}	32.81^{a}	27.06^{b}	23.10^{b}
	Control	38.28^{b}	45.36^{c}	46.02^{c}	29.08^{a}	16.77^{c}	14.83^{c}	31.09^{b}	24.44^{c}	21.67^{c}
Storage temperatures	A	**38.07^{a}**	**48.79^{a}**	**54.31^{a}**	**28.75^{a}**	15.05^{c}	9.99^{c}	**32.36^{a}**	22.43^{b}	18.99^{c}
	R	**38.07^{a}**	45.10^{b}	47.80^{b}	**28.75^{a}**	15.38^{b}	11.94^{b}	**32.36^{a}**	21.91^{b}	19.57^{b}
	F	**38.07^{a}**	41.12^{c}	43.16^{c}	**28.75^{a}**	**22.31^{a}**	**18.94^{a}**	**32.36^{a}**	**28.94^{a}**	**24.98^{a}**

a-e means followed by different superscript in each column are significantly different among pretreatment ($CaCl_2$- Control) and a-c means followed by different superscript in each column are significantly different among storage temperature (A-F) at ($p \leq 0.001$).
A = Ambient Temperature, R = Refrigeration Temperature, F = Freezing Temperature

After 30 days of storage, the significantly ($p \leq 0.001$) lowest a^* color value (12.43) was observed in case of combine $CaCl_2$ and KMS treated carrot powder and KMS treated powder showed the highest a^*value (24.21). The color a^*value (22.31) retention was maximum in case of sample stored at freezing temperature because percent loss was lower in freezing temperature (figure 4.2).

Even after 60 days of storage, KMS blanched sample recorded the highest a^* value and the least in case of combine $CaCl_2$ and KMS treated sample. From figure 4.2 percent loss (65.25) of a^* value was higher in sample stored at ambient compared to percent loss (34.12) in sample stored at freezing temperature. Baloch *et al.* (1981) reported that dipping in solution of bisulfite improved the color of the dried carrots.

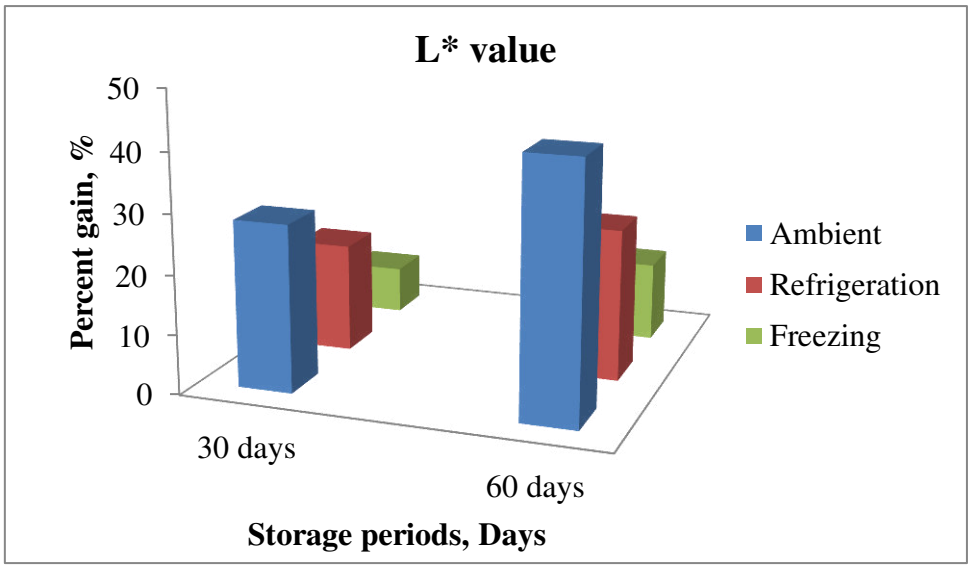
4.2.7.3 b^* value

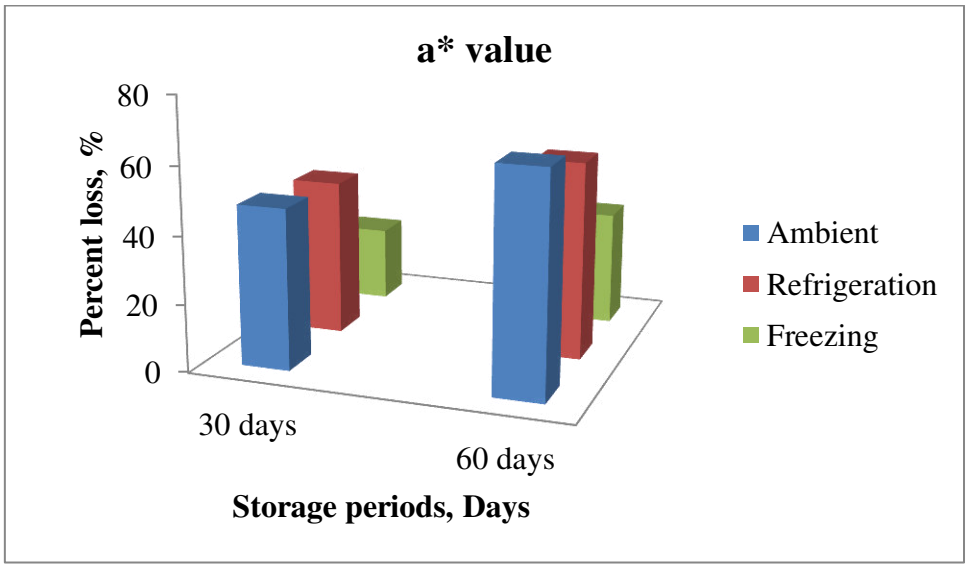
Table 4.7 explains significant ($p \leq 0.05$) effect of pretreatment on the b^* color value at 0 days. The b^* value (31.09) was significantly lower in control sample than that of other four samples. These results were lower than Raquel *et al.* (2014), who found b^* value (38.66-45.97) for dried carrot.

During storage of carrot powder it was also observed that b^* color value of all sample decreased. At 30 days of storage, b^* value (28.86) found to be higher in KMS blanched sample while lower value (19.93) found in sample that was blanched by combine $CaCl_2$ and KMS. Sample stored at freezing temperature scored the highest b^* value than ambient and refrigeration temperature.

Even after 60 days, carrot powder treated with KMS showed higher b^* value (25.71) while the lower value (16.82) in case of sample treated with combine $CaCl_2$ and KMS. From figure 4.2 maximum loss percentage (41.32) of b^* value was observed in ambient stored sample than sample stored at freezing temperature (loss percentage 22.81).

To ensure maximum color (L^*, a^* and b^* value) retention of carrot powder, blanched with KMS was the best pretreatment and stored at freezing temperature was found to be suitable for long term storage.





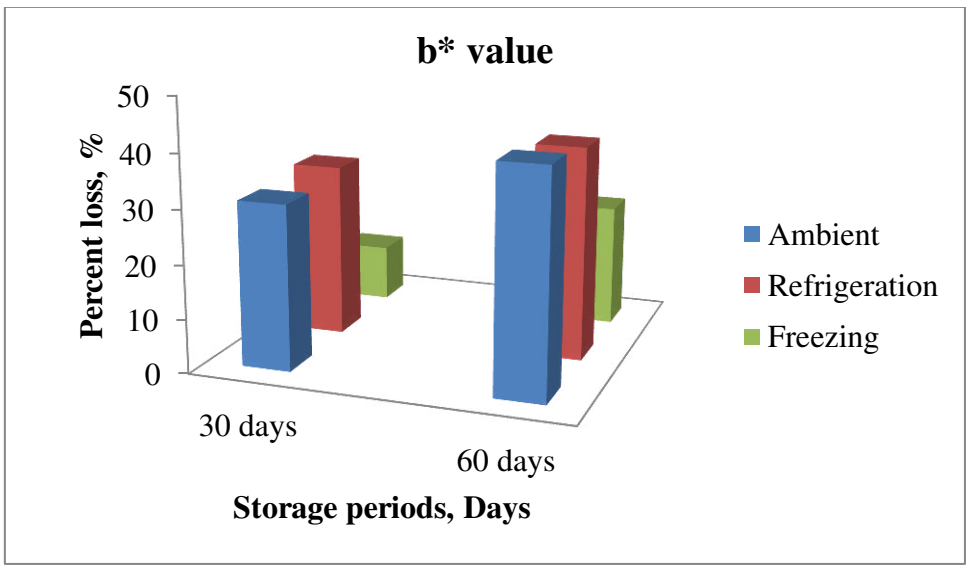
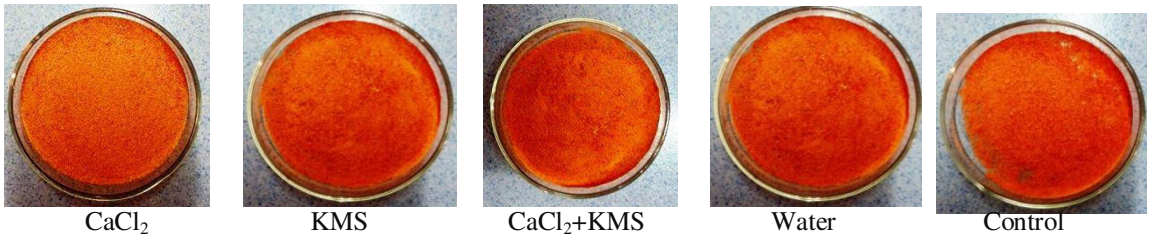
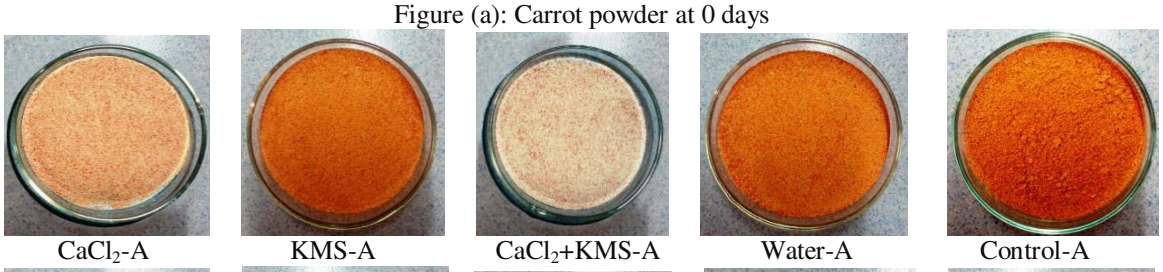


Figure 4.2 Percent loss of L^*, a^* and b^* value of color



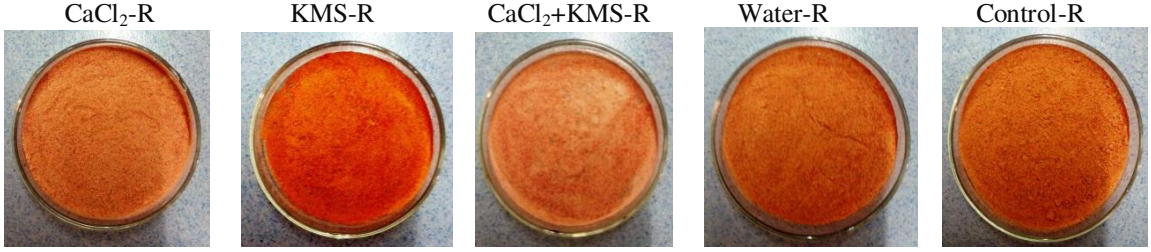
$CaCl_2$ KMS $CaCl_2$+KMS Water Control

Figure (a): Carrot powder at 0 days



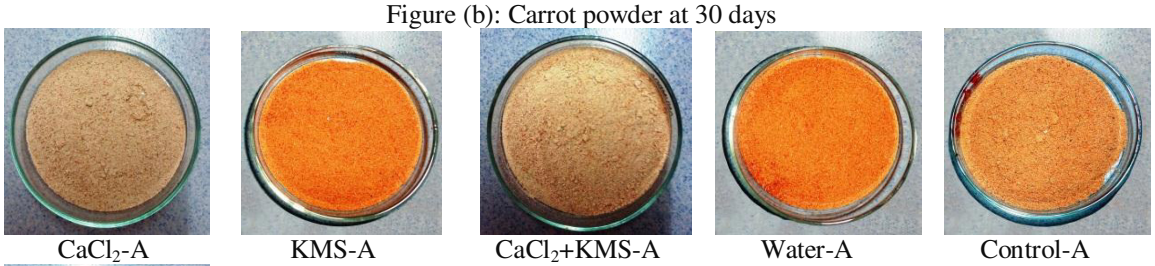
$CaCl_2$-A KMS-A $CaCl_2$+KMS-A Water-A Control-A

$CaCl_2$-R KMS-R $CaCl_2$+KMS-R Water-R Control-R

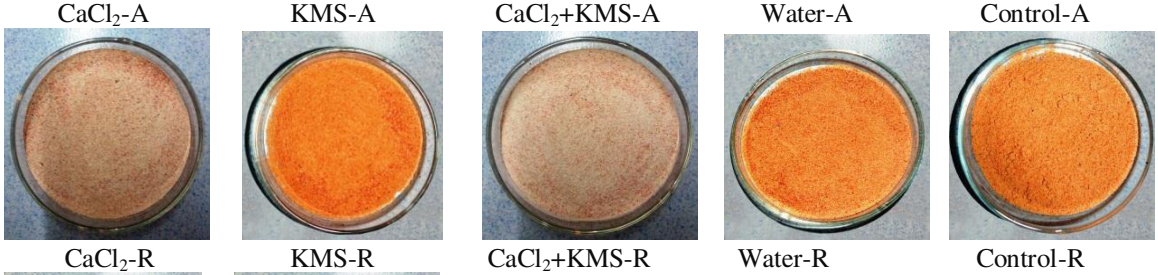


$CaCl_2$-F KMS-F $CaCl_2$+KMS-F Water-F Control-F

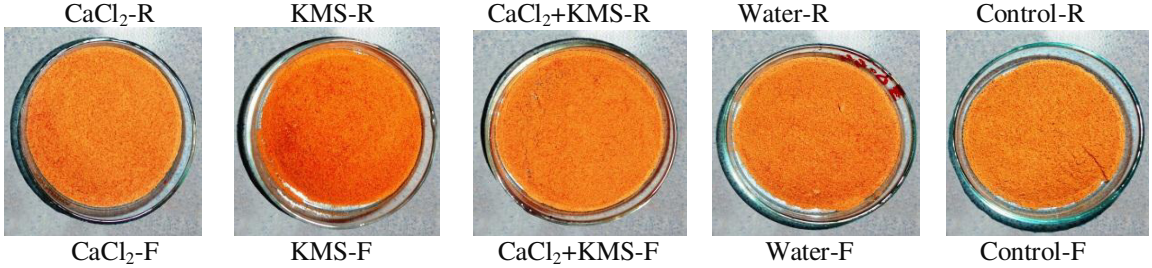
Figure (b): Carrot powder at 30 days



$CaCl_2$-A KMS-A $CaCl_2$+KMS-A Water-A Control-A



$CaCl_2$-R KMS-R $CaCl_2$+KMS-R Water-R Control-R



$CaCl_2$-F KMS-F $CaCl_2$+KMS-F Water-F Control-F

Figure (c): Carrot powder at 60 days

A = Ambient, R = Refrigeration, F = Freezing

Figure 4.3: Carrot powder at different storage periods

4.2 Effect of pretreatments and storage temperatures on functional properties

Statistical data from table 4.8and 4.10 present the functional properties of carrot powder exhibited significant ($p \leq 0.001$) variation with different pretreatments at 0 day. Also there were a significant ($p \leq 0.001$) effect of pretreatment and storage temperature on the prepared carrot powder storage at 30 and 60 days. Pretreatment and storage temperature interaction had a significant effect at $p \leq 0.01$ on rehydration ratio and bulk density at 60 and 30 days respectively. Also interaction had a significant effect at $p \leq 0.05$ on swelling capacity at 30 days and significant effect at $p \leq 0.001$ for rest of the functional properties. At 60 days of storage, pretreatment and storage temperature interaction had no significant effect on bulk density.

4.2.1 Water absorption index

From table 4.9 initially maximum WAI (15.81 g/g) was recorded in the sample which was treated by pure water blanching while control sample recorded minimum WAI (8.93g/g) which was compatible with Giami and Bekebain (1992), who found WAI (12.1 g/g) and (4.5 g/g) in raw fluted pumpkin flour and raw soya flour respectively.

At 30 days, water blanched sample showed the highest WAI value (13.24 g/g) and control sample showed the lowest WAI (7.67g/g). WAI (10.77g/g) was found to be higher in freezing stored sample compared to that of WAI (9.48g/g) in ambient stored sample. The higher and lower WAI 9.95g/g and 7.04g/g value were recorded in sample blanching with KMS solution and control sample respectively at 60 days of storage. The highest WAI (8.98g/g) obtained from the sample stored at freezing temperature and the least WAI (7.79g/g) obtained from sample stored at ambient. The WAI was found to decrease through the storage period may be due to increase of moisture content. Akubor and Badifu (2001) reported that the lower WAC of buckwheat flour could be attributed to the presence of lower amount of hydrophilic constituents in BWF.

In term of WAI of carrot powder, blanched with KMS solution was the appropriate pretreatment and suitable temperature was freezing storage temperature.

4.2.2 Rehydration ratio

The initial RR (12.07) was recorded the highest in case of sample which treated by water blanching and the least RR (8.17) was recorded in case of control sample (Table 4.9).

The range of rehydration ratio was obtained from the present study was higher from Davoodi *et al*. (2007) and Sra *et al.* (2014), who reported 3.6 to 4.98 as for dried tomato and 5.8 to 6.3 for dried carrot slices.

A reduction in RR was evidenced after one month storage in all samples with the control recording the lowest RR (5.94) and water blanched sample the highest RR (8.61), which was significantly higher ($p \leq 0.001$) than that of other samples. It may be due to increase of moisture content in carrot powder. RR (8.30) was higher in case of sample stored at freezing temperature compared to that of RR (6.87) and (6.48) of sample stored at refrigeration and ambient temperature respectively.

Even after 60 days storage, RR of the carrot powder further decreased. KMS treated powder rendered maximum RR (7.57) but control sample rendered the minimum RR (4.97). Among the storage temperature, rate of RR was significantly ($p \leq 0.001$) lower in freezing stored sample followed by refrigeration and ambient stored sample. To ensure higher RR, blanching with KMS was better treatment of carrot powder and stored at freezing temperature for long term storage.

The values of rehydration ratio presented in Table 4.6 (a) was in agreement with the results of Jay (2000), who reported that when the moisture content is increased rehydration ratio is decreased. Baloch *et al.* (1981) was found that dipping in solution of bisulfite improved the reconstitution of the dried carrots. Weier and Stocking (1949) also reported that the loss of rehydration due to changes in macromolecular components, including cellulose, pectin, hemicellulose and protein, which were adversely affected during pretreatment, dehydration and storage.

4.2.3 Swelling capacity

SWC showed a reduction in storage of carrot powder. The initial value of swelling capacity (SWC) from Table 4.9 shows significant difference at $p \leq 0.001$ among pretreatment of carrot powder. The range of SWC observed vary from 16.30 to 13.78 ml

Table 4.8 Effect of pretreatments, storage temperatures and their interaction on water absorption index, rehydration ratio and swelling capacity of carrot powder

Quality Parameters										
		Water absorption index			Rehydration ratio			Swelling capacity		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Factors	Pretreatment	20191.9***	4337.55***	682.07***	6015.39***	661.31***	525.84***	9361.75***	1735.05***	4178.99***
	Storage temperature	0 ns	492.24***	223.07***	0 ns	997.78***	303.36***	0	179.89***	1659.95***
	Pretreatment*Storage temperature	0 ns	33.18***	13.27***	0 ns	44.47***	7.25**	0	3.41*	31.81***
Coefficient of variance (CV)%		0.40	0.91	1.51	0.53	1.33	1.80	0.17	0.46	0.29

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

Table 4.9 Change in water absorption index, rehydration ratio and swelling capacity with different pretreatments and storage temperatures of carrot powder

Factors \ Quality Parameters		WAI (g/g)			RR			SWC (ml)		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Pretreatments	$CaCl_2$	10.96^{c}	8.66^{c}	7.70^{c}	9.42^{c}	7.36^{c}	5.87^{c}	15.89^{b}	14.73^{b}	13.46^{b}
	KMS	14.63^{b}	12.27^{b}	$\mathbf{9.95^{a}}$	8.24^{d}	7.53^{b}	$\mathbf{7.57^{a}}$	$\mathbf{16.30^{a}}$	$\mathbf{15.24^{a}}$	$\mathbf{14.08^{a}}$
	$CaCl_2$ + KMS	10.95^{c}	8.67^{c}	7.42^{d}	10.02^{b}	6.63^{d}	5.78^{c}	14.62^{d}	13.43^{d}	12.23^{d}
	Water	$\mathbf{15.81^{a}}$	$\mathbf{13.24^{a}}$	9.65^{b}	$\mathbf{12.07^{a}}$	$\mathbf{8.61^{a}}$	7.09^{b}	13.78^{e}	12.46^{e}	11.64^{e}
	Control	8.93^{d}	7.67^{d}	7.04^{e}	8.17^{e}	5.94^{e}	4.97^{d}	14.80^{c}	14.20^{c}	13.37^{c}
Storage temperatures	A	$\mathbf{12.26^{a}}$	9.48^{c}	7.79^{c}	$\mathbf{9.58^{a}}$	6.48^{c}	5.67^{c}	$\mathbf{15.08^{a}}$	13.76^{c}	12.47^{c}
	R	$\mathbf{12.26^{a}}$	10.04^{b}	8.29^{b}	$\mathbf{9.58^{a}}$	6.87^{b}	6.18^{b}	$\mathbf{15.08^{a}}$	13.97^{b}	12.95^{b}
	F	$\mathbf{12.26^{a}}$	$\mathbf{10.77^{a}}$	$\mathbf{8.98^{a}}$	$\mathbf{9.58^{a}}$	$\mathbf{8.30^{a}}$	$\mathbf{6.91^{a}}$	$\mathbf{15.08^{a}}$	$\mathbf{14.30^{a}}$	$\mathbf{13.44^{a}}$

a-e means followed by different superscript in each column are significantly different among pretreatment ($CaCl_2$- Control) and a-c means followed by different superscript in each column are significantly different among storage temperature (A-F) at ($p \leq 0.001$).
WAI = water absorption index, RR = rehydration ratio, SWC = swelling capacity, A = Ambient Temperature, R = Refrigeration Temperature, F = Freezing Temperature

while KMS blanched having the higher value and water blanched low. Similar values were found for buckwheat flour and refined wheat flour (15.77ml and 16.37ml, Baljeet *et al*., 2010) and brown rice flour and refined wheat flour (16.04ml and 16.98ml, Islam *et al.*, 2012). Sharoba *et al*. (2013) reported that blanching had a significant effect on the SWC because during blanching carrot, some components might be lost with water and the change of structural tissues might enhance the water uptake. KMS treated sample showed higher SWC which consisted with Benítez *et al*. (2011), who reported that SWC depended on fibre structure.

After 1 month, KMS blanching carrot powder was recorded the highest SWC (15.24ml) and the least SWC (12.46ml) in control sample. SWC (14.30ml) was significantly ($p \leq 0.001$) higher for sample stored at freezing temperature followed by the sample stored at refrigeration and ambient temperature.

At 60 days, the sample treated with KMS showed higher SWC (14.08ml) compared to that of SWC (11.64ml) of water blanched sample. But among storage temperature, sample stored at freezing showed higher SWC (13.44ml) and ambient showed lower SWC (12.47ml). To maintain higher SWC, KMS pretreatment and freezing temperature was best for carrot powder storage.

4.2.4 Degree of caking

DC exhibited by the various types of carrot powder which were significantly ($p \leq 0.001$) affected by pretreatments are shown in table 4.11. On the initial day of storage, sample blanching with KMS showed the lowest DC (7.59%) when control sample exhibited the highest DC (12.1%).

Even after one month of storage, KMS sample was recorded lower DC (8.51) compared to that of control sample which recorded significantly higher DC (13.12). Sample stored at freezing showed lower DC (10.57) compared to that of DC 10.77 and 11.07 at refrigeration and ambient temperature.

Study period 60 days showed DC value (9.31) again lower in case of KMS blanching sample while the DC value (13.81) was higher in control sample. The DC value (11.82) was recorded the maximum in the sample stored at ambient and the minimum DC (11.40) recorded at freezing stored carrot powder. To ensure lower degree of caking for carrot

powder, KMS pretreatment and freezing storage temperature was superior to other pretreatments and storage temperatures.

DC value of the prepared carrot powder increases through the storage periods may be due to increase in moisture content. The powder caking is an undesirable reaction, consisting initially in the powder transformation into an agglomerated and sticky material and resulting in decreased functionality, smoothness and quality loss; the main cause of agglomeration is the presence of plasticizing water onto the surface of particles (Aguilera *et al*., 1995).

4.2.5 Bulk density

On the initial day pretreatment showed significant effect at $p \leq 0.001$ on BD of carrot powder shown in table 4.11. The lowest BD (0.57g/ml) was observed in the KMS treated sample. This could be attributed to its high moisture content that resulted in more sticky powder granules occupying more space, thereby causing low BD. Water blanched sample had the highest BD (0.78g/ml) on the initial day of storage. Similar results were obtained by Ramachandran *et al*. (2014) for papaya powder with BD range 0.42 to 0.71g/ml and slight lower than Baljeet *et al*. (2010), who reported that buckwheat flour and refined wheat flour BD (0.81 g/ml) and (0.73 g/ml) respectively.

Storage for 30 days brought about a decrease in BD for all samples because of increase of moisture content. The water blanched sample exhibited the highest BD value (0.50g/ml) but untreated control and$CaCl_2$ treated sample both showed lower but not least BD value, control sample showed the least BD (0.37g/ml). Sample stored at freezing temperature rendered higher BD (0.55g/ml) against other sample stored at refrigeration and ambient temperature.

On the other hand, 60 days of storage sample that treated with KMS was recorded higher BD (0.43g/ml) while lower BD (0.27g/ml) recorded in control sample. The highest BD (0.45g/ml) obtained from sample that stored at freezing and the least BD (0.25g/ml) obtained from sample stored at ambient. So, KMS treatment and freezing storage temperature was better suited for carrot powder storage.

Results of this present study were similar with Janiszewska *et al.* (2008), who reported that powders having higher water content results in a reduction of bulk density as higher

Table 4.10 Effect of pretreatments, storage temperatures and their interaction on degree of caking, bulk density and solubility of carrot powder

Quality Parameters										
		Degree of caking			Bulk density			Solubility		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Factors	Pretreatment	1282.45^{***}	26226.5^{***}	27606.9^{***}	77.76^{***}	22.67^{***}	21.19^{***}	3167.99^{***}	309.53^{***}	11492.8^{***}
	Storage temperature	0^{ns}	825.35^{***}	609.10^{***}	0^{ns}	160.03^{***}	88.59^{***}	0^{ns}	1222.63^{***}	35454.8^{***}
	Pretreatment*Storage temperature	0^{ns}	15.10^{***}	33.75^{***}	0^{ns}	7.96^{**}	1.28ns	0^{ns}	552.45^{***}	1810.25^{***}
Coefficient of variance (CV)%		1.36	0.26	0.23	3.52	6.41	9.31	0.06	0.06	0.04

***F-value means significant at 0.1% level of significance, **F-value means significant at 1% level of significance, *F-value means significant at 5% level of significance, ns means not significant

Table 4.11 Change in degree of caking, bulk density and solubility with different pretreatments and storage temperatures of carrot powder

Factors \ Quality Parameters		DC (%)			BD (g/ml)			S (%)		
		0 days	30 days	60 days	0 days	30 days	60 days	0 days	30 days	60 days
Pretreatments	$CaCl_2$	9.20^{c}	10.99^{c}	11.98^{c}	0.61^{d}	0.39^{c}	0.33^{c}	91.62^{e}	91.15^{d}	84.34^{d}
	KMS	7.59^{e}	8.51^{e}	9.31^{e}	0.57^{e}	0.47^{ab}	**0.43^{a}**	93.84^{b}	91.32^{c}	**87.88^{a}**
	$CaCl_2$ + KMS	11.72^{b}	11.86^{b}	12.74^{b}	0.67^{c}	0.46^{b}	0.36^{bc}	92.96^{c}	91.75^{b}	87.16^{c}
	Water	8.56^{d}	9.54^{d}	10.26^{d}	**0.78^{a}**	**0.50^{a}**	0.40^{ab}	92.87^{d}	91.32^{c}	87.13^{c}
	Control	**12.01^{a}**	**13.12^{a}**	**13.81^{a}**	0.71^{b}	0.37^{c}	0.27^{d}	**94.88^{a}**	**92.10^{a}**	87.81^{b}
Storage temperatures	A	**9.81^{a}**	**11.07^{a}**	**11.82^{a}**	**0.67^{a}**	0.33^{c}	0.25^{c}	**93.23^{a}**	91.03^{c}	85.12^{c}
	R	**9.81^{a}**	10.77^{b}	11.63^{b}	**0.67^{a}**	0.42^{b}	0.37^{b}	**93.23^{a}**	91.36^{b}	86.45^{b}
	F	**9.81^{a}**	10.57^{c}	11.40^{c}	**0.67^{a}**	**0.55^{a}**	**0.45^{a}**	**93.23^{a}**	**92.20^{a}**	**89.02^{a}**

a-e means followed by different superscript in each column are significantly different among pretreatment ($CaCl_2$- Control) and a-c means followed by different superscript in each column are significantly different among storage temperature (A-F) at ($p \leq 0.001$).
DC = degree of caking, BD = bulk density, S = Solubility, A = Ambient Temperature, R = Refrigeration Temperature, F = Freezing Temperature

moisture content causes larger aggregations, which causes more empty voids between particles. Several authors reported that higher bulk density in samples due to higher crude fiber (Singh *et al*., 1996; Deshpande and Poshadri, 2011; Sawant *et al*., 2013).

Moreyra and Peleg (1980) said that bulk density (BD) provides an indication of cohesion and porosity like physical properties and may affect flowability and storage stability. There is a significant co-relationship between the moisture content and BD, i.e. the powders having higher moisture having larger bulk volume and lower bulk density. Product with lower moisture content would be less sticky and produce a free flowing powder of higher BD.

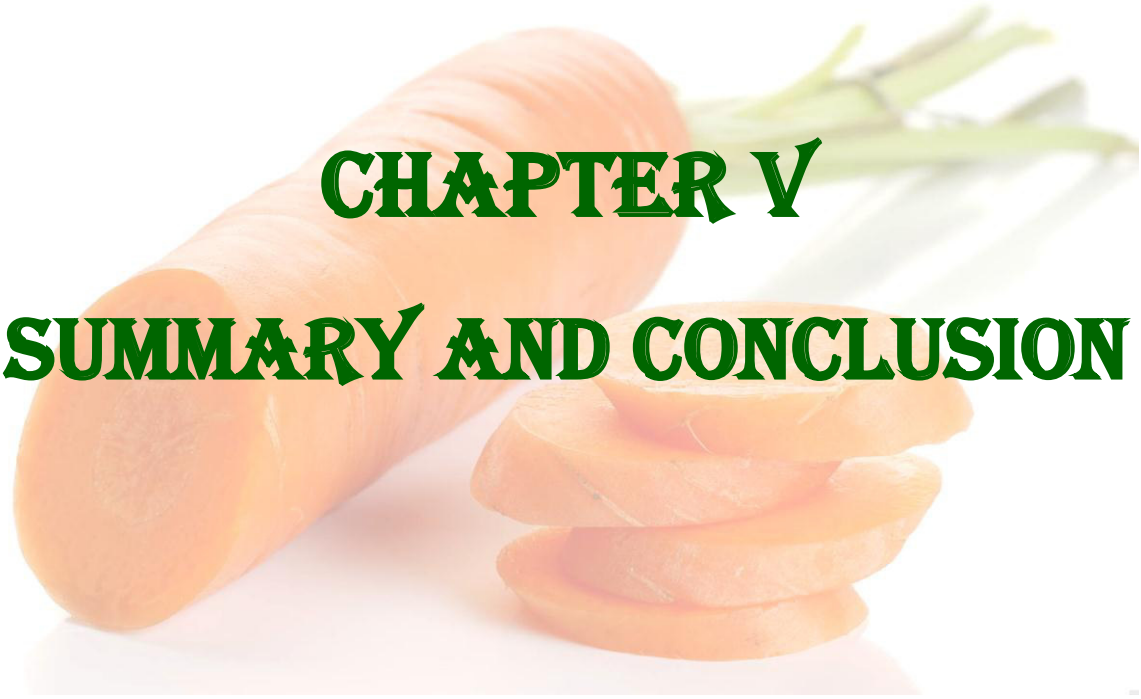
4.2.6 Solubility

Table 4.11 presents the solubility of the developed carrot powders and the changes during storage. A significantly ($p \leq 0.001$) higher solubility was recorded for control sample 94.88% on the initial day; whereas sample treated with $CaCl_2$ was recorded the lowest value (91.62%). These values were similar to that of spray-dried pitaya peel powder (90-92%) and mango powder (90-95%) but higher than that of pineapple powder (81.6%) (Ee *et al*., 2014; Abadio *et al*., 2004; Caparino *et al*., 2012).

The control sample was observed to maintain a high degree of solubility even after 1 month storage (92.10%) and $CaCl_2$ blanched samples recorded the lowest (91.15%). The highest solubility (92.20%) was noted for the sample stored at freezing temperature and the least (91.03%) for the sample stored at ambient temperature.

At 60 days of storage, it was observed that KMS sample with the least moisture content (8.38%) exhibited the highest percentage of solubility (87.88%). Solubility (89.02%) scored as higher in case of sample stored at freezing temperature and solubility (85.12%) scored as lower in case of sample stored at ambient. Regarding the solubility of carrot powder, freezing storage temperature and KMS pretreatment was found to be suitable temperature and pretreatment for carrot powder for long term storage.

As a result of increase in the moisture content, solubility of carrot powder decreased during storage. A similar observation was recorded in a study of Goula and Adamopoulos (2005) for tomato powder where an inverse co-relation was observed between moisture content and solubility of tomato powder.



CHAPTER V

SUMMARY AND CONCLUSION

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This research work was conducted to prepare carrot powder and to extensively study its shelf-life in terms of different pre-treatment and storage temperature.

The fresh and mature carrots were collected, washed with water and cut into cubes (0.3 to 0.5cm). Then pretreatment of carrot cubes by blanching with four different chemical solution. The cabinet dehydration technique was applied for drying of carrot cubes at 60^0±2C for 18 hours. Then prepared carrot powder packed into low density polyethylene pouch and stored at three different storage temperature; ambient (20±2ºC), refrigeration (4±2ºC) and freezing (-10±2ºC). The carrot powder was analyzed for different physicochemical and functional properties at 0 days, 30 days and 60 days interval.

Physico-chemical analysis, i.e., moisture, ash, fat, protein, fiber and β-carotene content of the carrot powder were carried out. Initially moisture content (7.90%), fiber content (18.34%) and β-carotene (2737.03µg/100g) were found to be higher in case of sample treated with KMS while fat content (3.81%) and ash content (7.57%) were found to be higher in case of combine $CaCl_2$ and KMS blanched sample. On the other hand protein content (8.86%) was higher for $CaCl_2$ blanched sample.

Functional properties such as water absorption index (15.81g/g), rehydration ratio (12.07) and bulk density (0.78g/ml) were found to be higher in case of water blanched sample. On the other hand $CaCl_2$ observed to be higher in solubility (94.88%). But KMS blanched sample were found to be higher in swelling capacity (16.30ml) and lower degree of caking (7.59%).

At 30 days study the best nutrient retentions (4.59% protein content, 11.06% fiber content and 1980.51µg/100gβ-carotene) and a^* value (24.21) and b^* value (28.86) were recorded for sample treated with KMS. The highest fat content (2.97%) and ash content (5.99%) were recorded for sample blanched by combine $CaCl_2$ and KMS solution while lower moisture content (7.67%) was recorded in water blanched sample. Sample stored at freezing temperature showed significantly ($p \leq 0.05$) higher nutrition compared to refrigeration and ambient temperature.

Most of the functional properties of carrot powder were observed to be significantly ($p \leq 0.001$) different due to pretreatment and storage temperature and decreased throughout the storage periods. Study period at 30 days, higher water absorption index (13.24g/g), rehydration ratio (8.61) and bulk density (0.50g/ml) obtained from water blanched sample when swelling capacity (15.24ml) obtained from KMS blanched sample.

After 60 days of storage, KMS blanched sample showed lower moisture content (9.22%) but higher protein (2.89%), fiber (6.87%) and β-carotene (1475.59µg/100g) which are reasonable properties for carrot powder. Carrot powders stored at freezing also showed lower moisture together with higher in other physico-chemical properties analyzed in present study.

In most cases sample treated with KMS observed to give higher value; water absorption index (9.95g/g), rehydration ratio (7.57), swelling capacity (14.08ml), bulk density (0.43g/ml), solubility (87.88%) and color (a^* and b^*) and lower in degree of caking (9.31%) than other treated samples. Sample stored at freezing was found to show most of the functional properties better than that of other storage temperatures.

Overall results of the study indicated that carrot powder treated with KMS and stored at freezing temperature exhibited better physico-chemical and functional quality. These qualities are very important parameter of carrot powder for use as convenience food ingredient. Consequently, this work will also open up more opportunities for the food processing industry because of it nutritional and economical importance.

Further research may be undertaken for further analysis of interaction effect of pretreatment and storage temperature. In addition, research will be encouraged for storage of other fruits and vegetable in powder form.

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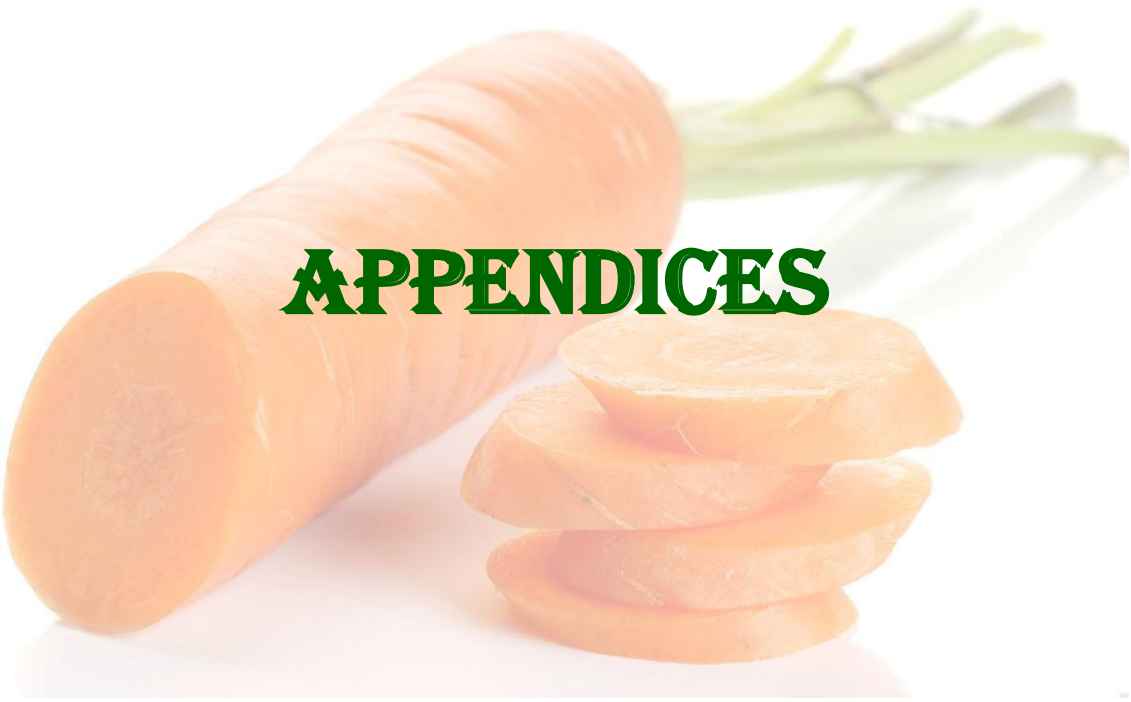

APPENDICES

APPENDICES

Appendix I

The ANOVA table of moisture content:

Moisture content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	8.13	2.033	4	4.98	1.25	4	3.42	0.86
Temperature	2	0	0	2	3.24	1.62	2	10.72	5.36
Treatment* Temperature	8	0	0	8	0.04	0.01	8	0.31	0.04

Appendix II

Duncan's Multiple Range Test of moisture content for different treatments:

DMRT of moisture content for different treatments										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treatment	Duncan Grouping	Mean	N	Treatment	Duncan Grouping	Mean	N	Treatment
A	7.9	6	2	A	8.81	6	2	A	10.26	6	5
B	7.44	6	1	B	8.71	6	1	B	9.99	6	3
C	7.17	6	5	C	8.56	6	5	B	9.97	6	1
D	7.03	6	3	D	8.3	6	3	C	9.74	6	4
E	6.32	6	4	E	7.67	6	4	D	9.22	6	2

Appendix III

Duncan's Multiple Range Test for moisture content at different storage temperatures:

DMRT for moisture content at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Temperature	Duncan Grouping	Mean	N	Temperature	Duncan Grouping	Mean	N	Temperature
A	7.17	10	1	A	8.8	10	1	A	10.56	10	1
A	7.17	10	2	B	8.44	10	2	B	9.84	10	2
A	7.17	10	3	C	7.99	10	3	C	9.10	10	3

Appendix IV

The ANOVA table for fat content:

Fat content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	3.62	0.90	4	4.45	1.11	4	6.58	1.65
Temperature	2	0	0	2	1.06	0.53	2	3.35	1.68
Treatment*temperature	8	0	0	8	0.14	0.02	8	0.39	0.05

Appendix V

Duncan's Multiple Range Test of fat content for different treatments:

DMRT of fat content for different treatments										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	3.81	6	3	A	2.97	6	3	A	2.57	6	3
B	3.57	6	4	B	2.75	6	2	B	2.24	6	2
C	3.43	6	2	B	2.71	6	4	C	2.02	6	1
D	3.22	6	1	C	2.5	6	1	D	1,83	6	4
E	2.44	6	5	D	1.85	6	5	E	1.55	6	5

Appendix VI

Duncan's Multiple Range Test for fat content at different storage temperatures:

DMRT for fat content at different storage temperatures										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	3.29	10	1	A	2.80	10	3	A	1.91	10	3
A	3.29	10	2	B	2.52	10	2	B	1.72	10	2
A	3.29	10	3	C	2.34	10	1	C	1.26	10	1

Appendix VII

The ANOVA table for ash content:

Ash content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	27.63	6.91	4	13.74	3.44	4	5.20	1.30
Temperature	2	0	0	2	1.68	0.84	2	2.68	1.34
Treatment*temperature	8	0	0	8	0.29	0.04	8	0.49	0.06

Appendix VIII

Duncan's Multiple Range Test of ash content for different treatments:

DMRT for ash content for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	7.57	6	3	A	5.99	6	3	A	4.62	6	3
B	5.59	6	5	B	4.65	6	2	B	4.12	6	2
C	5.31	6	1	C	4.44	6	1	C	3.8	6	1
D	5.24	6	2	D	4.32	6	5	D	3.54	6	4
E	4.85	6	4	E	4.06	6	4	D	3.50	6	5

Appendix IX

Duncan's Multiple Range Test for ash content at different storage temperatures:

DMRT for ash content at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Temper ature
A	5.71	10	1	A	4.99	10	3	A	4.28	10	3
A	5.71	10	2	B	4.66	10	2	B	3.93	10	2
A	5.71	10	3	C	4.42	10	1	C	3.55	10	1

Appendix X

The ANOVA table for protein content:

Protein content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	109.66	27.42	4	39.99	9.99	4	18.12	4.53
Temperature	2	0	0	2	18.3	9.15	2	11.53	5.76
Treatment*temperature	8	0	0	8	2.6	0.32	8	2.21	0.28

Appendix XI

Duncan's Multiple Range Test of protein content for different treatments:

DMRT of protein content for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	7.86	6	1	A	4.59	6	2	A	2.89	6	2
B	6.56	6	2	B	4.23	6	1	B	2.20	6	1
C	5.50	6	3	C	2.92	6	3	C	1.43	6	3
D	4.33	6	4	D	2.31	6	4	D	0.98	6	4
E	3.84	6	5	E	1.52	6	5	E	0.82	6	5

Appendix XII

Duncan's Multiple Range Test for protein content at different storage temperatures:

DMRT for protein content at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	5.62	10	1	A	4.11	10	3	A	2.45	10	3
A	5.62	10	2	B	3.02	10	2	B	1.60	10	2
A	5.62	10	3	C	2.20	10	1	C	0.94	10	1

Appendix XIII

The ANOVA table for fiber content:

Fiber content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	497.89	124.47	4	206.12	51.53	4	112.10	28.03
Temperature	2	0	0	2	184.21	92.1	2	139.50	69.76
Treatment*temperature	8	0	0	8	17.6	2.2	8	24.75	3.09

Appendix XIV

Duncan's Multiple Range Test of fiber content for different treatments:

DMRT of fiber content for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	18.34	6	2	A	11.1	6	2	A	6.87	6	2
B	16.92	6	4	B	8.30	6	3	B	4.39	6	4
C	15.47	6	3	B	8.30	6	4	C	4.32	6	3
D	13.94	6	1	C	7.01	6	1	D	3.41	6	1
E	6.66	6	5	D	3.01	6	5	E	0.86	6	5

Appendix XV

Duncan's Multiple Range Test for Fiber at different storage temperatures:

DMRT for fiber at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	14.26	10	1	A	10.5	10	3	A	6.83	10	3
A	14.26	10	2	B	7.59	10	2	B	3.46	10	2
A	14.26	10	3	C	4.47	10	1	C	1.62	10	1

Appendix XVI

The ANOVA table for beta-carotene content:

Beta-carotene content									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treat-Ment	4	1228730.36	307182.59	4	3093344.47	773336.12	4	3388379.13	847094.78
Temperature	2	0	0	2	3754700.72	1877350.36	2	3160453.88	1580226.94
Treatment* Temperature	8	0	0	8	114068.95	14258.62	8	106733.76	13341.72

Appendix XVII

Duncan's Multiple Range Test of beta-carotene content for different treatments:

DMRT of beta-carotene content at different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	2737.03	6	2	A	1980.51	6	2	A	1475.59	6	2
B	2661.32	6	4	B	1824.73	6	4	B	1356.24	6	4
C	2330.58	6	5	C	1632.2	6	5	C	1101.12	6	5
D	2287.15	6	1	D	1295.93	6	3	D	758.62	6	3
D	2257.45	6	3	E	1119.26	6	1	E	599.83	6	1

Appendix XVIII

Duncan's Multiple Range Test for beta-carotene content at different storage temperatures:

DMRT for beta-carotene content at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	2454.7	10	1	A	2010.21	10	3	A	1481.03	10	3
A	2454.7	10	2	B	1557.43	10	2	B	1001.76	10	2
A	2454.7	10	3	C	1143.94	10	1	C	692.04	10	1

Appendix IXX

The ANOVA table for water absorption index:

Water absorption index									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	196.27	49.07	4	147.8	36.94	4	43.51	10.88
Temperature	2	0	0	2	8.38	4.19	2	7.11	3.56
Treatment*temperature	8	0	0	8	2.26	0.28	8	1.69	0.21

Appendix XX

Duncan's Multiple Range Test of water absorption index for different treatments:

DMRT of water absorption index for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	15.81	6	4	A	13.24	6	4	A	9.95	6	2
B	14.63	6	2	B	12.27	6	2	B	9.65	6	4
C	10.96	6	1	C	8.66	6	1	C	7.70	6	1
C	10.95	6	3	C	8.67	6	3	D	7.42	6	3
D	8.93	6	5	D	7.67	6	5	E	7.04	6	5

Appendix XXI

Duncan's Multiple Range Test for water absorption index at different storage temperatures:

DMRT for water absorption index at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Temper ature
A	12.26	10	1	A	10.77	10	3	A	8.98	10	3
A	12.26	10	2	B	10.04	10	2	B	8.29	10	2
A	12.26	10	3	C	9.48	10	1	C	7.79	10	1

Appendix XXII

The ANOVA table for rehydration ratio:

Rehydration ratio									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	61.36	15.34	4	24.25	6.06	4	26.74	6.69
Temperature	2	0	0	2	18.29	9.15	2	7.71	3.86
Treatment*temperature	8	0	0	8	3.26	0.41	8	0.74	0.09

Appendix XXIII

Duncan's Multiple Range Test of rehydration ratio for different treatments:

DMRT of rehydration ratio for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	12.07	6	4	A	8.61	6	4	A	7.57	6	2
B	10.02	6	3	B	7.53	6	2	B	7.09	6	4
C	9.42	6	1	C	7.36	6	1	C	5.87	6	1
D	8.24	6	2	D	6.63	6	3	C	5.78	6	3
E	8.17	6	5	E	5.94	6	5	D	4.97	6	5

Appendix XXIV

Duncan's Multiple Range Test for rehydration ratio at different storage temperatures:

DMRT for rehydration ratio at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan G rouping	Mean	N	Tempe rature
A	9.58	10	1	A	8.29	10	3	A	6.91	10	3
A	9.58	10	2	B	6.87	10	2	B	6.18	10	2
A	9.58	10	3	C	6.48	10	1	C	5.67	10	1

Appendix XXV

The ANOVA table for swelling capacity:

Swelling capacity									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	24.72	6.18	4	28.89	7.22	4	23.74	5.93
Temperature	2	0	0	2	1.5	0.75	2	4.71	2.36
Treatment*temperature	8	0	0	8	0.11	0.01	8	0.36	0.05

Appendix XXVI

Duncan's Multiple Range Test of swelling capacity for different treatments:

DMRT of swelling capacity for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	16.30	6	2	A	15.24	6	2	A	14.08	6	2
B	15.89	6	1	B	14.73	6	1	B	13.46	6	1
C	14.80	6	5	C	14.20	6	5	C	13.37	6	5
D	14.62	6	3	D	13.43	6	3	D	12.23	6	3
E	13.78	6	4	E	12.46	6	4	E	11.64	6	4

Appendix XXVII

Duncan's Multiple Range Test for swelling capacity at different storage temperatures:

DMRT for swelling capacity at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature
A	15.08	10	1	A	14.30	10	3	A	13.44	10	3
A	15.08	10	2	B	13.97	10	2	B	12.95	10	2
A	15.08	10	3	C	13.76	10	1	C	12.47	10	1

Appendix XXVIII

The ANOVA table for degree of caking:

Degree of caking									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	92.03	23.01	4	80.43	20.11	4	80.24	20.06
Temperature	2	0	0	2	1.27	0.63	2	0.89	0.44
Treatment*temperature	8	0	0	8	0.09	0.01	8	0.20	0.02

Appendix XXIX

Duncan's Multiple Range Test of degree of caking for different treatments:

DMRT of degree of caking for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	12.01	6	5	A	13.12	6	5	A	13.81	6	5
B	11.72	6	3	B	11.86	6	3	B	12.74	6	3
C	9.20	6	1	C	10.99	6	1	C	11.98	6	1
D	8.56	6	4	D	9.54	6	4	D	10.26	6	4
E	7.59	6	2	E	8.51	6	2	E	9.31	6	2

Appendix XXX

Duncan's Multiple Range Test for degree of caking at different storage temperatures:

DMRT for degree of caking at different storage temperatures										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Temper ature
A	9.81	10	1	A	11.07	10	1	A	11.82	10	1
A	9.81	10	2	B	10.77	10	2	B	11.63	10	2
A	9.81	10	3	C	10.57	10	3	C	11.40	10	3

Appendix XXXI

The ANOVA table for bulk density:

Bulk density									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	0.17	0.04	4	0.07	0.02	4	0.09	0.02
Temperature	2	0	0	2	0.25	0.12	2	0.2	0.1
Treatment*temperature	8	0	0	8	0.05	0.01	8	0.01	0

Appendix XXXII

Duncan's Multiple Range Test of bulk density for different treatments:

DMRT of bulk density for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	0.78	6	4	A	0.50	6	4	A	0.43	6	2
B	0.71	6	5	AB	0.47	6	2	AB	0.40	6	4
C	0.67	6	3	B	0.46	6	3	BC	0.36	6	3
D	0.61	6	1	C	0.39	6	1	C	0.33	6	1
E	0.57	6	2	C	0.37	6	5	D	0.27	6	5

Appendix XXXIII

Duncan's Multiple Range Test for bulk density at different storage temperatures:

DMRT for bulk density at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Temp eratur e	Duncan Grouping	Mean	N	Tempe rature
A	0.67	10	1	A	0.55	10	3	A	0.45	10	3
A	0.67	10	2	B	0.42	10	2	B	0.37	10	2
A	0.67	10	3	C	0.33	10	1	C	0.25	10	1

Appendix XXXIV

The ANOVA table for solubility:

Solubility									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	35.35	8.84	4	3.66	0.91	4	50.87	12.72
Temperature	2	0	0	2	7.22	3.61	2	78.47	39.24
Treatment*temperature	8	0	0	8	13.05	1.63	8	16.03	2.00

Appendix XXXV

Duncan's Multiple Range Test for solubility at different treatments:

DMRT for solubility at different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	94.88	6	5	A	92.10	6	5	A	87.88	6	2
B	93.84	6	2	B	91.75	6	3	B	87.81	6	5
C	92.96	6	3	C	91.32	6	4	C	87.16	6	3
D	92.87	6	4	C	91.32	6	2	C	87.13	6	4
E	91.62	6	1	D	91.15	6	1	D	84.34	6	1

Appendix XXXVI

Duncan's Multiple Range Test for solubility at different storage temperatures:

DMRT for solubility at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature
A	93.23	10	1	A	92.20	10	3	A	89.02	10	3
A	93.23	10	2	B	91.36	10	2	B	86.45	10	2
A	93.23	10	3	C	91.03	10	1	C	85.12	10	1

Appendix XXXVII

The ANOVA table for L^* value:

L^* value									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	41.33	10.33	4	616.58	154.15	4	771.95	192.99
Temperature	2	0	0	2	378.08	189.04	2	627.47	313.73
Treatment*temperature	8	0	0	8	180.7	22.59	8	148.16	18.52

Appendix XXXVIII

Duncan's Multiple Range Test of L^* value for different treatments:

DMRT of L^* value for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	40.19	6	1	A	50.99	6	1	A	54.98	6	3
B	38.28	6	5	B	47.84	6	3	B	53.92	6	1
B	37.91	6	2	C	45.36	6	5	C	46.02	6	5
B	37.02	6	3	D	40.12	6	4	D	44.79	6	4
B	36.97	6	4	D	39.04	6	2	E	42.38	6	2

Appendix XXXIX

Duncan's Multiple Range Test for L^* value at different storage temperatures:

DMRT for L^* value at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	38.07	10	1	A	48.79	10	1	A	54.31	10	1
A	38.07	10	2	B	45.10	10	2	B	47.80	10	2
A	38.07	10	3	C	40.12	10	3	C	43.16	10	3

Appendix XXXX

The ANOVA table for a* value:

a* value									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	13.05	3.26	4	542.46	135.62	4	421.48	105.37
Temperature	2	0	0	2	336.6	168.3	2	443.18	221.59
Treatment*temperature	8	0	0	8	110.08	13.76	8	63.88	7.99

Appendix XXXXI

Duncan's Multiple Range Test for a* value for different treatments:

DMRT of a*value for different treatments										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	29.44	6	4	A	24.21	6	2	A	18.55	6	2
A	29.08	6	5	B	20.32	6	4	B	16.11	6	4
A	28.99	6	2	C	16.77	6	5	C	14.83	6	5
A	28.76	6	3	D	14.15	6	1	D	10.09	6	1
B	27.51	6	1	E	12.43	6	3	E	8.54	6	3

Appendix XXXXII

Duncan's Multiple Range Test for a* value at different storage temperatures:

DMRT for a* value at different storage temperatures										
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature	Duncan Grouping	Mean	N	Temper ature
A	28.75	10	1	A	22.31	10	3	A	18.94	10	3
A	28.75	10	2	B	15.38	10	2	B	11.94	10	2
A	28.75	10	3	B	15.05	10	1	C	9.99	10	1

Appendix XXXXIII

The ANOVA table for b^* value:

b^* value									
	0 days			30 days			60 days		
Source	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square	DF	Anova SS	Mean Square
Treatment	4	14.23	3.56	4	320.79	80.2	4	300.62	75.15
Temperature	2	0	0	2	307.25	153.62	2	218.85	109.42
Treatment*temperature	8	0	0	8	97.73	12.22	8	15.75	1.97

Appendix XXXXIV

Duncan's Multiple Range Test of b^* value for different treatments:

DMRT of b^* value for different treatments											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment	Duncan Grouping	Mean	N	Treat-ment
A	33.07	6	3	A	28.86	6	2	A	25.71	6	2
A	32.81	6	4	B	27.06	6	4	B	23.10	6	4
A	32.56	6	2	C	24.44	6	5	C	21.67	6	5
A	32.29	6	1	D	21.84	6	1	D	18.59	6	1
B	31.09	6	5	E	19.93	6	3	E	16.82	6	3

Appendix XXXXV

Duncan's Multiple Range Test for b^* value at different storage temperatures:

DMRT for b^* value at different storage temperatures											
0 days				30 days				60 days			
Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature	Duncan Grouping	Mean	N	Tempe rature
A	32.36	10	1	A	28.94	10	3	A	24.98	10	3
A	32.36	10	2	B	22.43	10	1	B	19.57	10	2
A	32.36	10	3	B	21.91	10	2	C	18.99	10	1

Treatment 1 = $CaCl_2$, Treatment 2 = KMS, Treatment 3 = $CaCl_2$ + KMS, Treatment 4 = Water, Treatment 5 = Control

Temperature 1 = Ambient, Temperature 2 = Refrigeration, Temperature 3 = Freezing