PREPARATION AND STORAGE QUILITY OF GREEN CHILLI (CAPSICUM ANNUUM L.) POWDER AND PASTE

A THESIS

BY

MD. SHAHID ALI BABU
STUDENT NO.: 1705005
SESSION: 2017-2018
Thesis Semester: July - December, 2018

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

DEPARTMENT OF HORTICULTURE
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
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DEDICATED

TO

BELOVED PARENTS

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ABSTRACT

A study was conducted at the Laboratory, Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University, Dinajpur during April to June, 2018 with the green chilli fruits of the variety Bogra Local having three objectives: (i) to develop techniques for preserving green chilli as powder and paste, (ii) to assess the quality of those powder and paste during storage, and (iii) to find suitable techniques for their storage quality. The six treatments compared in the Completely Randomized Design replicated four were: T1- green chilli with pedicel, cut longitudinally, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T2- green chilli with pedicel, cut longitudinally, sliced, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T3- green chilli without pedicel, cut longitudinally, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T4- green chilli without pedicel, cut longitudinally, sliced, treated with 0.01% KMS solution, rinsed, sun-dried and made into powder; T5- green chilli with pedicel, treated with 0.01% KMS solution, slight water was added and made into paste, and T6- green chilli without pedicel, treated with 0.01% KMS solution, slight water was added and made into paste. Nine traits noted were: (i) ratio of the green chilli fruits to the powder, (ii) ratio of the green chilli fruits to the paste, (iii) moisture content, (iv) vitamin C content, (v) recovery of the powder and the paste from the fruits, (vi) storage quality of the products for: (a) colour, (b) flavour (c) texture, and (d) overall acceptability. After getting the powder (T1 - T4) and the paste (T5 - T6), those were stored for 0, 30 and 60 days for their storage quality for the moisture and vitamin C contents. But their sensory traits noted on the 0 and the 60^{th} day of storage were: colour, flavour, texture and overall acceptability. The results clarified that the chilli had initially 86.6% moisture and 115.71mg/100g vitamin C. The moisture contents in all the six products increased little up to the 60^{th} day as their values were from 4.08 - 5.25 to 4.33 - 6.68 and 87.08 - 87.35 to 92.39 - 93.39%, in T3 - T4 and T5 - T6, respectively. But the vitamin C contents decreased much up to the 60^{th} day. Still, the highest amount was noted in T4 (38.19) and T6 (17.32mg/100g) among the powder and the paste, respectively. Moreover, all the six treatments had notable statuses in terms of sensory evaluation test (6.50 - 7.70 for the colour, 6.10 - 7.40 for the flavour, 6.50 - 7.70 for the texture and 6.47 - 7.60 for the overall acceptability) in case of both the powder and the paste forms) up to the 60^{th} day of storage. So, overall, the treatment T4 was the best one. The study further paved the ways to work with other varieties, other treatments (whole fruit with pedicel and whole fruit without pedicel), long storage period up to one year, various bagging materials for moisture and oxygen free conditions, microbial contaminations, packing sizes, etc. to develop new and more sustainable technologies to preserve the green chilli powder and the paste with their adequate nutritional quality, hygiene and value addition too.

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CHAPTER I

INTRODUCTION

Chilli (*Capsicum* spp. L., family Solanaceae) is a diploid species with mostly 2n = 2x = 24 chromosomes but wild ones with 2n = 2x = 26 are also noted (Pickersgill, 1991). It is usually called hot peppers, red peppers, pod peppers, cayenne peppers, paprika, pimento and capsicum in different countries. Pungent fruits of all the species of *Capsicum* are jointly called chilli (Berke and Shieh, 2001). India, Mexico, Japan, Ethiopia, Uganda, Nigeria, Thailand, Turkey, Indonesia, China, Pakistan and Bangladesh are its major growers. But India is the largest producer and consumers of chilli in the orb (Salvador, 2002). It is one of the five major spices in Bangladesh ranking 2^{nd} in the area but 4^{th} in the production. Here, its area and production in 2015 - 2016 were 2,51,872 acres and 1,30,260 tons, respectively (BBS, 2017). And most of its varieties grown here are pungent varying from very high to mild one. Its pungency is due to the alkaloid 'Capsaicin' which has high medicinal values. Capsaicin is an amide derivative of vanilly lamine and 8 methyl-non-trans-6-enoic acid (Maria *et al*., 1993). Besides adding pungency and red colour i.e. capsanthin to dishes, it is rich in vitamins A, B, C and E, and minerals Ca, P, F etc.

Consumption of chilli is increasing day by day. And those are used in fresh, processed, dried whole, frozen, canned and as value added products like powder, oleoresin, paste and chilli oil which are in vogue in the present global market. In food and beverage industries, it is used in the form of oleoresin which permits better distribution of colour and flavor. Chilli is exported in different forms: fresh green fruits, whole ripe fruits, dried fruits, chilli powder and chilli oleoresin to South Asian countries, the USA and Canada (Govindarajan *et al.*, 1985). Its powder is widely used for food flavoring and coloring meat food, snack food and sauces. Chilli powder has many useful properties-making it vital in ayurvedic medicine to fight against many diseases, destroys harmful toxins and stimulates gastric juices helping in digesting food. It also helps in clearing nasal congestion, relieves throat infection and acts as a pain killer in muscle. Chilli is generally found in three forms: fresh green, raw red and red grind. Usually, red chilli is dried in the open sun without any pre-treatment in Bangladesh (Elias and Hossain, 1984). It was noted (FAO, 1995) that chilli is usually dried as whole fruits without slicing as the whole fruit is more attractive to consume than the sliced one. But the green chilli fruit has short shelf-life (about 7days) under ambient storage conditions. So, during the peak to the end of the harvesting season (February - April), microbes cause its severe damage due to lack of proper processing and preservation techniques. Thus, in the off season, its price becomes high manifolds.

Quality drop in spices and spice products pose a major threat during storage as those are hygroscopic and highly sensitive to moisture causing caking, discolouration, hydrolytic rancidity, mold growth and insect attack. Carcinogenic metabolites, aflatoxins etc. are major issues in stored spices. Harvesting is done as the fruits are well ripe with a moisture content of 65 - 75%, which must be brought down to 8 - 10% to prepare the dried spices and their powder.

Many researchers studied the processing and preservation of red chilli and noted the nutritional compositions in terms of the proximate analyses, ascorbic acid and mineral contents (Saimbhi *et al.*, 1977; Khadi *et al.*, 1987; Esayas, 2011 and Anon., 2002). Even, processing treatments influence its chemical constituents affecting the storage life too. Unfortunately, there are very limited research works on the drying, processing and preservation of green chilli. In fact, the processing of green chilli in the form of powder is still a very new technology. Meanwhile, the preservation of green chilli as paste and mixed pickles has been studied by Ahmed *et al.* (2001) and Molla *et al.* (2007). Recently, the feasibility of green chilli processing and preservation in the form of powder has also been reported by Sarker (2008) and Tummala *et al.* (2008). Oppositely, during the peak to the end of the harvesting season, green chilli is found wasted at the farm level due to the lack of proper processing and preservation technologies in Bangladesh. Hence, the processing and preservation of green chilli are vital to minimize the postharvest losses as well as enhance the value addition, thus, contributing to the national economy of the country. It may also save time in cooking, particularly for office-going ladies by providing ready-to-use green chilli powder and paste. Again, it may pave the way for industrialization, export earnings and employment opportunities.

So, the present piece of work was designed to study the green chilli fruits of the variety Bogra Local with these three specific objectives:

a) To develop techniques for preserving green chilli in the forms of powder and paste
b) To assess the quality of green chilli powder and paste during their storage, and
c) To find suitable preservation techniques for quality powder and paste of green chilli.

CHAPTER II

REVIEW OF LITERATURE

Various researchers studied the chemical composition, health benefits, postharvest losses, processing and preservation techniques, and storage quality of chilli (whole fruits, powder and paste forms). Those works have been reviewed critically and presented in this chapter under few captions.

2.1 Chemical composition

Leung *et al.* (1972) observed that the composition of ripe chilli was: moisture content 65.4%, protein 6.3%, fat 1.4%, mineral 2.1%, fiber 15.0%, energy 116Kcal and ascorbic acid 96mg/100g. Oppositely, 100g dry chilli contains moisture 15.30%, protein 11.7%, fat 12.4%, mineral 16.9%, fiber 13.4%, and energy 288Kcal and vitamin C 184mg/100g.

According to Bajaj *et al.* (1980), on an average, chilli contains dry matter 22.02%, ascorbic acid 131.06mg/100g, oleoresin 68.53 ASTA units, coloring matter 67.38 ASTA units, capsaicin 0.34%, crude fibre 26.75% and total ash 6.69% besides vitamin P.

Nutritional composition in chilli varies from variety to variety (Kaur *et al.*, 1980) and also location to location (Raina and Teotia, 1985 and Teotia and Raina, 1986).

The pungency of chilli is for a group of related alkaloids 'Capsaicinoids' found only in the genus *Capsicum* (Bekele, 2009; Pordesimo *et al.*, 2004 and Sanatombik and Sharma, 2008).

Anon (2002) analyzed that the dry fruit of chilli (moisture content 8%, wet basis/wb) contained 10.55% protein, 69.82% carbohydrates, 31.48mg/100g ascorbic acid and small quantities of minerals, vitamins A and B. The green chilli fruits (moisture content 88%, wb) contain 18.00% protein, 9.46% carbohydrates, 242.5mg/100g ascorbic acid and small amounts of vitamins A, B and E. The pungent nature of chilli is due to the crystalline volatile alkaloid capsaicin ($C_9H_{14}O_2$).

Usha and Kowsalya (2002) found that green chilli contains 2835mg/100g total carotenes, 1045.9mcg/100g β carotene which forms 36.9% of the total carotenes.

Savita (2005) found significantly higher yield of 0.498kg/2kg of fresh chilli, ascorbic acid 165.23mg/100g, capsaicin 0.405%, oleoresin 13.80%, color units 144.34 ASTA units and lower aflatoxin content 1.77ppm in chilli dried in an electric dryer.

Ahmed *et al.* (1987) observed that capsaicin content was more in red ripened and dry fruits compared to green chilli. The capsaicin content ranged from 1.0 - 107.2mg/100g fruits at the ripe stage. They argued that fruit size and the maturity stage affected the amount of capsaicinoind contents. The capsaicin content was inversely related to fruit diameter, length and thickness.

Osuna-García *et al*. (1998) and Aniel-Kumar and Subba-Tata (2009) investigated the ascorbic acid contents of chilli and reported that the content gradually increased from green to red ripening but decreased later on, such as in partially or fully dried peppers.

2.2 Health benefits

According to Denre (2014), apart from providing basic nutrition, chilli is well known for its health benefits; antioxidant constituents and antioxidant activities have been reported. Ascorbic acid (vitamin C) is one of the most powerful antioxidants that scavenges harmful free radicals and also regenerates other antioxidants like tocopherol to its functional state.

Ozgur *et al*. (2011) stated that chilli contains a wide range of phytochemicals: neutral and acidic phenolic compounds, which are vital antioxidants and may decline the risk of degenerative, mutagenic and chronic diseases. The phytochemicals in peppers are reported to possess many biochemical and pharmacological properties, such as antioxidant, anti-inflammatory, anti-allergic and anti-carcinogenic activities. The anti-carcinogenic activity of phenolic compounds is due to the inhibition of N-nitroso compound formation *in vitro*.

Rao and Rao (2007) mentioned that carotenoids (fat-soluble antioxidants) found in chilli, have received significant interest by researchers due to their antioxidant properties. According to Denre (2014), the health benefits of phenolic is linked primarily to their antioxidant potential. Phenolics are effective antioxidants as the radical's products of those molecules are resonance stabilized and, thus, relatively stable. To overcome the potential hazards from oxidative damage in the body, consumption of a diet rich in antioxidant phenolic including flavonoids and phenolic acids is considered as the first line defense against highly reactive toxicants.

2.3 Postharvest losses

Since green chili is highly perishable like other green vegetables, those are also subjected to huge postharvest losses during the peak production season mainly during transportation, storage, and marketing (Rahman *et al.*, 2012).

Nyanjage *et al*. (2005) reported that green chilli deteriorated rapidly during handling and storage due to poor post-harvest handling leading to huge losses. Generally, the products were handled in batches which are subjected to a wide range of environmental shocks.

Bosland and Votava (2000) reported that green chilies are highly susceptible to water loss, sunscald and heat damage. Fresh green chilii losses water very quickly after harvest and begin to wrinkle and change colour within a few days without refrigeration. Darkening, shriveling or rotting of stem indicates that green chili was not harvested recently.

Hameed *et al.* (2013) opined that the most encountered postharvest problems for green chilii were strong physiological activities, shriveling, wilting and fungal diseases. Even, those were sensitive to chilling injury if stored at or below 7^{o}C.

Sarker *et al.* (2012) investigated that during the harvesting season (February - March), the local varieties of green chilli were wasted at the farm level due to the lack of suitable processing and preservation technology in Bangladesh.

Drying is one of the oldest methods of food preservation. Drying preserves foods by removing enough moisture from foods to prevent decay and spoilage. According to Wade *et al.* (2014), the moisture contents of chilli at the harvest is 70-80% (wb) and very prone to insect and fungal attacks during their storage. Excessive delay in the drying results in growth of microbial flora and subsequent loss of quality or total storage. For processing and to increasing the shelf life, their moisture is to be reduced by drying and dehydration.

Naik *et al.* (2001) opined that in dried chilli, >15% moisture content was critical with respect to mold growth while discolouration of red pigment during storage was greatly influenced by both the prevailing moisture and the temperature.

2.4 Drying system

As per Sharma *et al.* (1994), the cabinet type of natural convection drier was suitable for drying a small quantity of chilli on a household scale while the integrated solar collector-cum-drying system was suitable for the drying of a limited crop volume on farms and the indirect multi-shelf forced convection drier was suitable for industrial uses.

Tunde-Akintunde (2010) reported that chilli is generally harvested and dried for preservation in the country during the rainy season. Drying of chilli is usually carried out traditionally by drying in the open air by exposure to sunlight, which usually takes up to 10days. However, due to the drawbacks of sun-drying, which include time-consuming and exposure to contamination, various alternatives like the uses of solar and hot-air dryers have been recommended. Those dryers have the benefits of rapid drying and hygienic products, while hot-air drying has an extra advantage of providing uniform drying.

In Bangladesh, generally red chilli is dried in the open sun without any pretreatment (Elias and Hossain, 1984). To improve the quality of dried chilli, industrial dryers are used to decrease the drying time and provide uniform and hygienic processing conditions (Chaethong *et al*., 2012).

Malchav *et al*. (1982) noted that the colour stability in paprika was strongly dependent on the temperature of the air used in drying of the product: the higher was the temperature, the lesser was the stability of the pigments during storage. Lowering the storage temperature and reducing the package free space volume improved carotenoid retention (Lee *et al*., 1992) as refrigeration reduced the free radical formation (Biacs *et al*., 1992).

Parikh (2015) reported that the use of vacuum drying was more feasible in food, pharmaceutical, plastic and textile industries due to energy conservation as less energy is required to dry the products. Vacuum drying tends to retain the integrity of the original item without reducing the nutrients in the foods.

Singh *et al.* (2015) also reported that the bulk density was influenced by the methods of drying like sun-drying of green chilli powder (0.1690 - 0.1782g/ml), tray-drying green chilli powder (0.1841 - 0.1845g/ml), vacuum green chilli powder (0.1690 - 0.1705) and lyophilize green chilli powder (0.1532 - 0.1589g/ml).

Mangaraj (1998) dried red chilli in different methods: open sun-drying, mechanical drying, solar cabinet drying and green house type solar drying. Both punched and un-punched chilli fruits were used for each of the methods. It was inferred that punching samples saved considerable drying time in all the drying methods compared to the un-punched samples but punched samples lost some pungency.

Kachru and Srivastava (1990) treated the red chilli in the hot lye solution consisting of 0.5% potassium hydroxide in water at 80 ± 2°C. Chilli fruits were washed thoroughly in fresh water and dried in a cabinet drier. They found better retention of colour and pungency, and significantly reduced drying time.

Savita (2005) found significantly higher yield (0.498kg/2kg of fresh chilli), ascorbic acid (165.23mg/100g), capsaicin content (0.405%), oleoresin (13.80%), colour units (144.34 ASTA units) and lower aflatoxin content (1.77ppb) in chilli dried in an electric dryer.

Singh *et al*. (2015) noted that the green chilli powder obtained by lyophilizer drying method was most acceptable for color, flavor, pungency and texture followed by other drying methods: sun, tray and vacuum and also revealed that the variety Kashianmol gave the most acceptable response for color, flavor, pungency and texture followed by the variety Pusasadabahar.

2.5 Pretreatment of green chilli, storage environment and product quality

Tummala *et al.* (2008) evaluated the dehydrated green chilli powder with various pretreatments of green chilli in different shapes: longitudinal slits, 1-cm cuts and paste. The dehydrated green chilli powder had considerable amount of crude protein (13.38%) and were also rich in crude fiber (36.19%). The critical moisture contents were 8.92 and 10.45%, which equilibrated at 50 and 54% RH of green chilli powder with 1-cm cuts and green chilli powder with salt samples, respectively.

Sarker *et al.* (2012) evaluated the effects of various common processing treatments: (a) without pedicle and cut longitudinally plus treated with 0.01% potassium meta-bisulphate (KMS), (b) without pedicel and sliced, (c) without pedicle as a whole, and (d) as a normal whole green chilli with pedicle, on the shelf-life during storage in high density polyethylene (HDPE) and low density polyethylene (LDPE) packages at room temperature. The nutritional quality in terms of proximate compositions of ascorbic acid, β carotene and mineral contents of green chilli powder were also assessed. The chilli powder from the treatment (a) showed the highest stability up to 195 days in the HDPE pouches. The results revealed that the nutritional qualities in all the samples of green chilli powder were better than that of the red chilli powder. Ascorbic acid content got reduced about 50% in all the samples due to the processing, while β carotene content got significantly increased compared to the fresh green chilli.

The major pungent components capsaicin, dihydro capsaicin and homodihydro capsaicin contents increased about 10% with the dose of 10KGy irradiation and in contrast notable decrease was recorded in those components with storage (Ayhan and Feramuz, 2004).

The whole fruit and the powdered form of chilli variety Byadagidabbi and Byadagikaddi retained higher oleoresin yield, colour value, capsaicin and % moisture contents when packed in metalized polyester polyethylene (aluminum) and stored under cold store even up to eight months without deterioration in all the quality (Kalpana, 2003).

La Niora was a red pepper variety grown in Tadla Region, Morocco which was used to produce paprika after sun-drying. The paprika qualities (nutritional, chemical and microbiological) were evaluated immediately after milling from September - December. Sampling time mainly affected paprika color and the total capsaicinoid and ascorbic acid contents. The commercial quality was acceptable and no aflatoxins were found, but the microbial load sometimes exceeded the permitted levels (Zaki *et al.*, 2013).

Abrar *et al.* (2009) studied the proximate composition, total phenolics and aflatoxin. Irradiation and storage showed non-significant effects on the proximate composition and total phenolics whereas the irradiation showed notable effects on the aflatoxins compared to control. It was opined that for better quality retention, red chilli could be stored safely in polyethylene bags. The use of radiation could be helpful for the preservation of chilli with respect to the production of aflatoxin during their storage.

Khatun (2012) studied the effects of packaging materials on the keeping quality of green chilli powder. The results showed that the samples packed in aluminum foil absorbed less moisture, retained more ascorbic acid and had longer shelf-life than those of the polyethylene packet. The colour, flavour, pungency and texture of green chilli powder were appreciably retained when packed in the aluminum foil.

Attri *et al.* (2002) reported that the physiological loss in terms of weight was high in ambient temperature compared to samples stored at low temperature. The % loss of physiological weight in green chilli powder with and without preservative stored at ambient temperature did not show much variation. There was an increasing trend in physiological loss at ambient and low temperature storages with the duration of storage period. Physiological loss was inevitable during the storage period. Physiological loss was due to moisture, which leaded to shrinkage, tough, fibrous and wilting of the produce.

Koraddi (1995) noted that the green chilli powder stored in various packaging systems indicated that the powder stored in polythene bag, plastic container and LDPE bags retained up to 3-4 months and aluminum foil and HDPE bags retained up to 4-5 months at the ambient temperature.

Severini *et al.* (2003) studied the auto-oxidation of red chilli as affected by two packaging films and found that the vacuum conditions were necessary for the better preservation of chilli, but the effectiveness of the vacuum was apparent only if that was combined with a good oxygen barrier provided by the selected packaging film.

Oxidation of food ingredients like vitamins, pigments and aroma compounds is the most vital causes of quality loss during food processing and also the main deteriorative reaction in microbiologically safe foods like dry and frozen products (Anderson and Lingnert, 1997). Since air contains 21% oxygen, it is a potent and a major force in accelerating oxidation of the stored products packed in containers. If the containers are packed with little or no air space above the product, the oxidation can be avoided (Anon., 2000). Oxygen sensitive foods should thus be stored in packages with initial contents of head space oxygen below 2% to ensure the long shelf-life (Rooney, 1983). The growth of aerobic microorganisms is supported by oxygen and thus the removal of the oxygen from the modified atmosphere has been shown to extend the microbiological shelf-life (Sanjeev and Ramesh, 2006).

Vaccum packaging of whole chilli and chilli powder retained better colour, capsaicin content, optimum moisture (10 - 12%), safe fungal load and free from aflatoxin than gunny bags (Chetti *et al.,* 2009).

Morais *et al.* (2001) reported that the overall decomposition rate of pigments was dependent on the storage time. And in the presence of light and oxygen, the effects of storage time were the most decisive factors while the impact of oxygen was the least.

Mujumdar (2004) noted that all varieties of food products used in daily life need to increase their shelf-life using permitted preservatives. Toontom *et al.* (2010) presented the results that chilli is one of the crop which gets spoiled easily. So, it is mandatory to apply any preservative method to expand its shelf-life.

Khatun (2012) studied the effects of drying methods, packaging materials and potassium meta-bisulphate (KMS) solution on the keeping quality of the green chilli powder and noted that treating with 500ppm of KMS and mechanical drying process were most acceptable in respect of color, flavour, pungency and texture followed by sun-dried green chilli powder treated with only 500ppm KMS.

Kanner *et al*. (1977) found that the colour deterioration was lower at high moisture contents (10 - 14%) with corresponding low values of 0.4 - 0.6. The high moisture content of 18% resulted in the microbial growth (Slade and Levine, 1991 and Lee *et al*., 1992), non-enzymatic browning and cracking (Kanner *et al*., 1977 and Lee *et al*., 1991).

Osuna-Garcia and Wall (1998) noted that the colour loss in ground paprika could be minimized by 50% during their storage at the ambient temperature and humidity by increasing the pre-storage moisture content to 15%. The sorption isotherm studies of Naik *et al*. (2001) indicated that the moisture content of 9.6% (Equilibrium Relative Humidity, ERH 57%) was quite safe for the storage of Byadgi chilli variety at the ambient conditions whereas the moisture level > 11.2% induced the mold growth.

A moisture content of 10 - 11% with subsequent storage at -16° C was best with the least colour loss in ground capsicum (Guzman *et al*., 1973 and Malchev *et al*., 1982).

Mamun *et al.* (2016) studied the quality changes of chilli powder. The quality parameters of moisture content, ash content, acid soluble ash content, refractive index and volatile fat were assessed which were directly related to quality, processing technique, storage conditions, packaging and the microbial load of chilli powder. The result showed that the moisture and ash of chilli powder were about 4.40 - 6.00% and 5.28 - 6.19%, respectively.

Storage at higher temperature increased the rate of colour destruction and resulted in the blackening of whole chilli. That deterioration was also attributed to non-enzymatic browning, accentuated by both the moisture contents and the ambient temperature (Krishnamurthy and Natarajan, 1973).

Phillip *et al*. (1971) gave a scheme of oxidation of capsanthin by oxygen, wherein the hydroxyl group of capsanthanin was oxidized. The carotenoid degradation in paprika was explained as an auto-oxidative process (Chen and Gutmanis, 1968 and Chou and Breene, 1972). But such auto-oxidation might be coupled with enzymatic activity (Kanner *et al*., 1977 and Biacs *et al*., 1992).

Wilbur Scoville in 1912 developed a scale to measure the “Heat levels” of chilli. In the original form, Govindarajan (1985) had also the opinion that during the prolong storage, unlike the marked fall in colour, little effect was noted in the pungency. Kim *et al*. (2002) also argued that the capsaicinoids in the red pepper were not related to the colour stability.

Kurain and Starks (2002) analyzed capsaicinoids in chilli for both the undried and the dried stages. They found 1250ppm capsaicin and 540ppm dihydrocapsaicin in undried chilli and 8840ppm capsaicin and 3940ppm dihydrocapsaicin in dried chilli fruits.

Topuz and Ozdemir (2004) stated that the fresh red peppers had mid-levels of capsaicinoid capsaicin, dihydrocapsaicin, homodihydrocapsaicin and nor dihydrocapsaicin. Rajender Singh *et al.* (2004) observed variation in capsaicin contents from 0.435 (ARCH-236) to 0775mg/100g (CH-1) and colouring matter in the range of 90.80 (CH-1) to 139.19 (CH-9) ASTA unit. Furthermore, they reported that CH-3 and CH-6 hybrids with high colouring matter and low pungency were most suited for the processing industry.

Bozkurt and Erkmen (2004) produced hot pepper paste by traditional open pan and vaccum production techniques and stored at 37°C for 46 days. The results revealed that, brown pigment formation in the paste increased during the storage periods. The traditionally produced hot pepper paste was best with respect to flavour and colour scores produced by the vaccum technique. The results indicated that hot pepper paste produced with vaccum technique after an initial fermentation period was of good quality, safer and acceptable.

The total colour is considered as the quality indicator during the thermal processing of green chilli puree. The pungency during the thermal processing decreased as the capsaicin contents got reduced from 559 to 441μg/g and colour unit decreased from 8500 - 7480 (Ahmed, 2002). Moreover, Ahmed *et al*. (2002) evaluated the thermally processed red chilli puree and stored chilli paste, and found kinetic changes in colour during the thermal treatment of red chilli puree and storage of puree. But the paste was microbiologically stable with no major changes in other physico-chemical traits studied.

Bera *et al*. (2001) opined that the addition of ascorbic acid in the thermally processed red chilli powder helped in the retention of red colour, checked the growth of microorganisms and also enriched the ascorbic acid content of the stored product.

Mixing seeds with flesh of paprika and chilli, stabilized the red colour of the powder, the degree of stabilization was dependent on the antioxidants present in seeds. Powder needed storage under cool conditions without light. The commercial hammer mill produced a powder of equal quality to stone milled product (Klieber and Bognato, 1999).

Mamun *et al.* (2016) concluded that the spices may be of high risk products as those have many pathogenic bacteria, coliform and mould. Packed branded chilli powder samples were less contaminated. So, it is clear that the unpacked local spices may be highly contaminated with microorganisms. Thus, more studies are needed to find out the ways of contamination and proper preparation processing. Finally, the aseptic techniques at all the stages of production and processing must be ensured to prevent contamination and quality loss of chilli powder.

2. 6 Panel test for quality

Scoville test, a panel of volunteers were asked to determine the dilution of the chilli pepper solution that no longer could cause burning discomfort in the mouth (Borges, 2001). The hottest chilli pepper recorded was Habanero with a Scoville pungency of 577,000 in contrast to the sweet Italian Bell pepper with a pungency of the 0 unit (Bellringer, 2001). Indian scientists have recently claimed that Tezpurchilli grown in the North East zone had the highest Scoville units of 8,55,000 (Anon., 2000). In *C. annuum*, the ratio of capsicum to dihydrocapsaicin varied from 1.36 - 1.71 (Estrada *et al*., 1997) while Boronat *et al*. (1999) had reported a ratio of 0.64 - 1.94.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the material used and the methods employed in the present study. All the technological, physical and chemical analyses, shelf-life, sensory evaluation and statistical analyses are described here under different captions.

3.1 Location of the experiment

The research work was conducted at the Laboratory, Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh.

3.2 Study period

The present study was conducted during April to June, 2018.

3.3 Experimental type, design and replication

The study was a laboratory work with a single factor conducted in the completely randomized design (CRD) with six treatments and four replications for each treatment.

3.4 Chilli variety used

The variety Bogra Local (Plate 1) was chosen for the study.

Plate 3.1. The green chilli fruits of the variety Bogra Local used in the study

3.5 Collection of the green chilli fruits

The mature and fresh green chilli fruits were purchased in April, 2018 from the local Bahadur Bazar, Dinajpur town, Dinajpur. Disease free, insect attacked and physically damaged fruits were discarded and only fresh fruits were selected, washed using tap water and kept under fan to dry-up the surface water of washing before using in the study.

3.6 Treatments

There were six treatments in the study which were as follows (Table 3.1).

Table 3.1. The details of the six treatments used in the present study

Treatments designated	Detail descriptions of the six treatments compared in the study
T1	Fruits with intact pedicel, cut longitudinally (Plate 3.2), dipped in 0.01% KMS solution, rinsed and sundried on a silver tray and blended to make the powder
T2	Fruits with intact pedicel, cut longitudinally, sliced transversely (Plate 3.3), dipped in 0.01% KMS solution, rinsed and sundried on a silver tray and blended to make the powder
T3	Fruits without pedicel, cut longitudinally (Plate 3.4), dipped in 0.01% KMS solution, rinsed and sundried on a silver tray and blended to make the powder
T4	Fruits without pedicel, cut longitudinally, sliced transversely (Plate 3.5), dipped in 0.01% KMS solution, rinsed and sundried on a silver tray and blended to make the powder
T5	Fruits with intact pedicel, fresh fruits (Plate 3.6) dipped in 0.01% KMS solution and blended with 100 ml water to make the paste
T6	Fruits without pedicel, fresh fruits (Plate 3.7) dipped in 0.01% KMS solution and blended with 100 ml water to make the paste

Plate 3.2. Preparing the green chilli fruits for the treatment T1

Plate 3.3. Preparing the green chilli fruits for the treatment T2

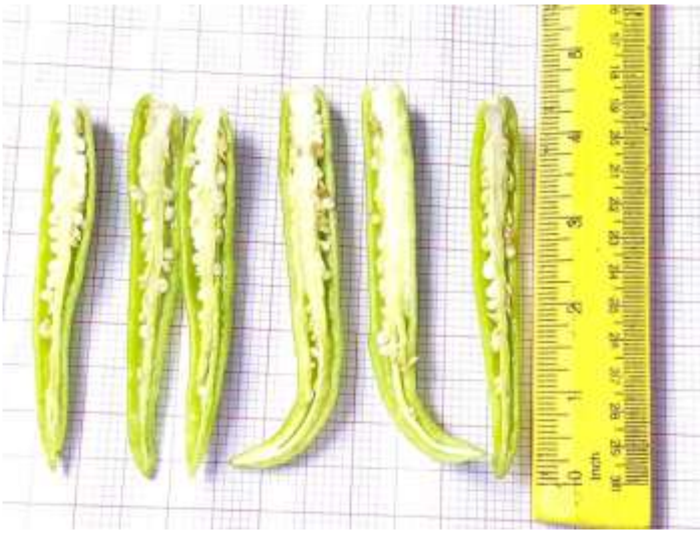

Plate 3.4. Preparing the green chilli fruits for the treatment T3

Plate 3.5. Preparing the green chilli fruits for the treatment T4

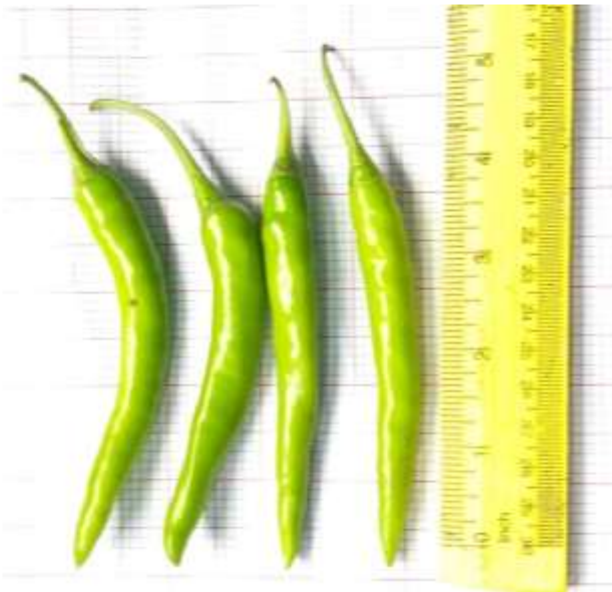

Plate 3.6. Preparing the green chilli fruits for the treatment T5

Plate 3.7. Preparing the green chilli fruits for the treatment T6

For the treatments T1 to T4, sun-dried fruits were uses to have the powder. So, for each replication, 2.5kg of green chilli fruits were dried and used. In contrast, for T5 and T6, only 0.5kg of green fruits for each replication was used. Besides that, 100ml of plain water was added during the blending for ease of blending to have the two paste products. Then, after getting the paste, the paste was spread on trays and the trays were kept at the 30^{O} slanting manner for 10minutes to drain out the excess water from the paste.

3.7 Storing the powder/paste for quality study

Then the powder/paste was divided in to three parts (for analyses at 0, 30th and 60th day of storing), packed in the high density polyethylene bags (Plates 3.8 and 3.9), heat sealed and stored at the room temperature (25-30^{O}C) up to 60 days (15th April to 15th June) to study the shelf-life and the storage quality of the six types of products developed.

Plate 3.8 Storing of the prepared green chilli powder in the HDPB (T1 to T3)

Plate 3.9 Storing of the prepared green chilli powder and paste in the HDPB (T4 to T6)

3.8. Data recorded

To achieve the aforesaid objectives of the study, in total, the following nine parameters were recorded.

A) Ratio of the green chilli fruits to the powder
B) Ratio of the green chilli fruits to the paste
C) Moisture content (%, wet weight basis)
D) Ascorbic acid content (mg/100g)
E) Recovery of the powder and paste from the chilli fruits (%, wet weight basis)

F) Storage quality/shelf life:

   a) Colour of the stored product
   b) Flavour of the stored product
   c) Texture of the stored product, and
   d) Overall acceptability of the stored product

For the storage quality, data were collected at 0, 30th and 60th day after storing for moisture and vitamin C contents. But for the sensory evaluation, data were collected at two stages, at 0 and 60th day after storing.

3.8.1 Ratio of the green chilli fruits to the powder

The ratio of the green chilli fruits to the powder was assessed with the following formula.

$$\text{Ratio of the green chilli fruits to the powder} = \frac{\text{Weight of the green chilli fruits used}}{\text{Weight of the powder obtained}}$$

3.8.2 Ratio of the green chilli fruits to the paste

The ratio of the green chilli fruits to the paste was determined using the following formula.

$$\text{Ratio of the green chilli fruits to the paste} = \frac{\text{Weight of the green chilli fruits used}}{\text{Weight of the paste obtained}}$$

3.8.3 Moisture contents in % (wet weight basis)

The moisture contents were assessed at the following two circumstances.

For the fresh chilli fruits (to have the bench mark information): It was done just after buying the fresh chilli fruits to have the benchmark information about the fresh chilli fruits.

For the stored products (to have the comparative information): This was done at the 0, the 30th and the 60th day of storing to get the comparative information about the six treatments used.

Procedure: In both the circumstances, the procedure of Ranganna (1997) was used. For that, 5g of the sample was taken in the moisture dish and weighed with an electric balance. Then the moisture dish with the sample was placed in an electric oven and dried at the 105^{O}C for 24hours. After drying, the moisture dish with the sample was removed from the oven and cooled down in a desiccator. After cooling, the weight of the moisture dish with the sample was recorded. From that weight, the moisture content of the sample was calculated using the following formula.

Let,

Weight of the empty moisture dish = W_1 (g)

Weight of the sample + moisture dish = W_2 (g)

Weight of the sample (dry) + moisture dish = W_3 (g)

Now,

$$\%\ \text{Moisture content (wet weight basis)} = \frac{W_2 - W_3}{W_2 - W_1}$$

Then the mean value of such four observations for each treatment was expressed in %.

3.8.4 Ascorbic acid/vitamin C contents in mg/100g

Like the moisture contents, the ascorbic acid contents were also assessed at the following two contexts.

For the fresh chilli fruits (to have the bench mark information): It was done just after buying the fresh chilli fruits to have the benchmark information about the fresh chilli fruits.

For the stored products (to have the comparative information): This was done at the 0, the 30th and the 60th day of storing to get the comparative information about the six treatments assessed.

Reagent used: For both the cases, the following reagents were used for the same.

(i) 6% Metaphosphoric acid (HPO_3): It was prepared by dissolving 60g of HPO_3 and 80ml of glacial acetic acid in distilled water and volumed up to 1 litre.

(ii) Standard ascorbic acid solution: For that, 10mg% of L-ascorbic acid solution was prepared by dissolving ascorbic acid in 6% metaphosphoric acid solution.

(iii) Dye solution: It was prepared by dissolving 260mg of the sodium salt of 2, 6-dichloro-phenol indophenol in one litre of distilled water containing 210mg/litre of sodium bicarbonate.

Procedure: In both the circumstances, the procedure of Plummer (1971) was used. And the flowing steps were followed.

Standardization of the dye solution: Five ml of the standard ascorbic acid solution was taken. A micro burette was filled in with the dye solution. Then the mixture was titrated with the dye using the phenolphthalein indicator solution to a pink coloured end point, which persisted at least for 15seconds. Then the dye factor was calculated using the following formula.

Dye factor = 0.5/titre.

Preparation of the sample: Five gram of the sample was taken in a 100ml beaker with 50ml 6% meta-phosphoric acid and then that was transferred to a blender and homogenized with the same concentration of metaphosphoric acid. After blending, that was filtered and centrifuged @ 2000rpm for 5minutes. The supernatant homogenized liquid was transferred to a 100ml volumetric flask and was made up to the mark with 6% metaphosphoric acid.

Titration: Five ml of the aliquot was taken in a conical flask and titrated with the dye solution which persisted at least for 15seconds. The ascorbic acid contents of the samples were calculated using the following formula.

$$\text{Ascorbic acid (mg/100g of the sample used)} = \frac{T \times D \times V1}{V2 \times W} \times 100$$

Where,

T = Titre

D = Dye factor

V_1 = Volume made up

V_2 = Volume of the extract taken for the estimation, and

W = Weight of the sample taken for the estimation

3.8.5 Sensory evaluation test of the products

The sensory evaluation test of the six treatments i.e. the six products produced from the green chilli fruits was conducted through a testing panel using the nine-point hedonic scale. And the hedonic scale used was as follows:

9 = like extremely	6 = like slightly	3 = dislike moderately
8 = like very much	5 = neither like or dislike	2 = dislike very much
7 = like moderately	4 = dislike slightly	1 = dislike extremely

And the panelists were selected from the students and employees, Department of Food Engineering and Technology, HSTU who frequently took part in such evaluation tests. The panelists were asked to assign the appropriate numerical score to each sample for these four characteristics: colour, flavor, taste and overall acceptability of the given six products developed in the study.

3.8.6 Statistical analyses

The results expressed as the mean ± standard deviation were analyzed for the variances (ANOVA) and the means were separated using Duncan’s Multiple Range Test (DMRT) for the level of significance with the IBM SPSS statistical package, version 20 (SPSS Inc., Chicago, IL).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the present study are presented in tables of this chapter and discussed with the help of the available literature and usual scientific phenomena.

4.1 Initial moisture content of the fresh green chilli fruits (bench mark value)

The initial moisture content of the fresh green chilli fruits was 86.6% (Table 4.1). This value is almost similar to that of the report of Sarker *et al*. (2012) who found 85.54%. But Wade *et al*. (2014) reported the value as 70 - 80% at the time of harvest, which was slightly lower than the present finding. This variation could probably be due to varietal and cultural differences, e.g. irrigation/rain-fed condition as irrigation increases succulence in chilli fruits and vice-versa.

Table 4.1 Moisture and ascorbic acid contents of the fresh green chilli fruits of the variety Bogra Local (bench mark value)

Fresh green chilli fruits	Moisture content (%)	Ascorbic acid content (mg/100g)
	86.6 ± 0.61	115.71 ± 0.67

The values are Means ± Standard Deviations.

4.2 Initial ascorbic acid content of the fresh green chilli fruits (Bench mark value)

The initial ascorbic acid content of the fresh green chilli fruits was 115.71mg/100g (Table 4.1). This value is also almost similar to that one of Igbokwe *et al*. (2013) who claimed that fresh green chilli fruits had the ascorbic acid content of 116.08mg/100g. Oppositely, the present value is greater as argued by Sarker *et al*. (2012) who found less, i.e.110 mg/100g of fresh green chilli fruits. Such disparity may also occur possibly on account of the varietal difference, freshness of the fruits etc.

4.3 Yield/recovery of the dried green chilli powder

The % yield of the green chilli powder from the sundried green chilli fruits is given in the Table 4.2 which has variation among the six treatments. The % powder obtained from the sundried samples ranged from 8.4 - 11. The % yield of the green chilli powder was slightly less than the result obtained by Jyothirmayi *et al*. (2008) who got 12.4% green chilli powder. The variation in the % yield of powder from the raw chilli fruits may be attributed to the varieties used, stages of maturities of the fruits, the methods of the drying and the extent of drying used in those two separate studies. Nonetheless, the higher yield is a good sign of more % dry matter in the green fruits. And such fruits are cherished for the chilli powder production on the commercial basis for higher yield and fiscal profit as well. Again, in case of the yield, the higher values were noted with both T3 and T4 with the intact pedicels with the fruits but the lower values were obtained with both T1 and T2 without the pedicels. This may happen due to the fact that the pedicels had more dry matter % than the respective green fruits.

Table 4.2 Yield of the powder and the paste from the green chilli fruits of the variety Bogra Local

Treatments	% Yield
T1	8.8 ± 0.66
T2	8.4 ± 0.72
T3	11.0 ± 0.59
T4	10.0 ± 0.61
T5	140.0 ± 0.85
T6	135.0 ± 0.77

Values are Means ± Standard Deviations.

4.4 Yield/recovery of the paste of the green chilli

In contrast to the yield of the green chilli powder, the % yield of the green chilli paste was as high as 135 - 140% as shown in Table 4.2 which was much higher than chili powder. The higher yield (more than 100%) was found because of three reasons: (a) The fruits used in making the paste were at the fresh green stage i.e. succulent, (b) During making the paste for the ease of pasting 100ml water was added, and (c) The small amount of the water which was present in the treating solution of the KMS used.

4.5 Changes in the moisture % of the powder and the paste during their storage

The Table 4.3 presents the changes in the moisture contents of the dried green chilli powder and the paste during their storage up to 60days.

On the 0 day, the moisture content varied notably ($P < 0.05$). The range was as low as 4.08 (T3) to as high as 87.35 (T6). But it fluctuated from 4.08 (T3) to 5.25 (T4) among the four treatments with powder while 87.08 (T5) to 87.35 (T6) between the two paste treatments.

On the 30th day, the moisture content varied significantly too ($P < 0.05$) among the six treatments. The range was from as low as 4.08 (T3) to as high as 87.35 (T6). However, it ranged from 4.16 (T3) to 5.54 (T4) among the four treatments with powder but 90.52 (T6) to 90.67 (T5) between the two paste treatments. So, there was a gradual as well as almost parallel rise in the moisture contents in all the six treatments irrespective of the powder or the paste forms. That was quite natural as at the 30th day of storage, i.e. the time of the year was 15th April to 15th May. At that time % atmospheric humidity was in the rising direction and so, the products had also absorbed some moisture from the atmosphere to have equilibrium in the conditions.

Table 4.3 Changes in the moisture contents of the powder and the paste of the green chilli fruits variety Bogra Local during their storage up to 60days

Treatments	Moisture contents (%) at the three storage periods (day)		
	0	**30th**	**60th**
T1	4.78 ± 0.12^{bc}	5.37 ± 0.33^{b}	5.89 ± 0.20^{d}
T2	4.18 ± 0.19^{cd}	4.54 ± 0.27^{c}	4.89 ± 0.23^{e}
T3	4.08 ± 0.09^{d}	4.16 ± 0.07^{c}	4.33 ± 0.19^{f}
T4	5.25 ± 0.13^{b}	5.54 ± 0.17^{b}	6.68 ± 0.15^{c}
T5	87.08 ± 0.75^{a}	90.67 ± 0.42^{a}	93.05 ± 0.28^{a}
T6	87.35 ± 0.89^{a}	90.52 ± 0.51^{a}	92.39 ± 0.47^{b}

Values are Means ± Standard Deviations.
$^{a-e}$The means bearing the different letters in each column are significantly different ($P < 0.05$).

Finally, at the 60th day, the moisture content varied significantly as well ($P < 0.05$) among the six treatments. The range was from as low as 4.33 (T3) to as high as 93.05 (T5). However, it fluctuated from 4.33 (T3) to 6.68 (T4) among the four treatments with powder while 92.39 (T6) to 93.05 (T5) between the two paste treatments. So, there was a gradual as well as almost parallel rise in moisture contents in all the six treatments compared irrespective of the powder or the paste forms. That was quite natural as at the 60th day of storage, the time of the year was 15th May to 15th June; at that time % atmospheric humidity was high and so, the products had absorbed some moisture from the atmosphere.

Again, at the 60th day of storage, the moisture contents of green chilli powder ranged between 4.33 (T3) to 6.68% (T4), which was within the range of 2.9 - 9.7% as reported by Wade *et al*. (2014). Tummala *et al.* (2008) claimed a moisture content of 7.20 % in 1cm cut dried green chilli powder. This is a good sign of the shelf-life of green chilli powder against the oxidative and microbial deterioration as well (Toontom *et al*., 2012). Mahadevaih *et al.* (1976) found that the moisture content was higher than 15% in chilli powder which was critical with respect to the mold growth and unfit for consumption.

The results of the present study revealed that the moisture contents of the green chilli powder ranged within the acceptable limit as specified by previous researchers. Oppositely, at the same storage period (60th day) of green chilli paste, moisture contents were found to have ranged within 92.39 (T6) to 93.05% (T5). That may be attributed to the absorption of some moisture from the atmospheric humidity through the polyethylene bags as the storage time was 15th April to 15th June, i.e. humid months of the year polyethylene bags were not 100% moisture proof.

4.6 Changes in the ascorbic acid contents during the storage periods

The changes in the ascorbic acid contents during the storage of green chilli powder and the paste are shown in the Table 4.4.

Table 4.4 Changes in the ascorbic acid contents (in mg/100g) of **the powder and the paste of the green chilli fruits variety Bogra Local during their storage up to 60 days**

Treatment	Storage periods (Day)		
	0	30th	60th
T1	49.43 ± 0.74[c]	42.41 ± 0.31[c]	33.39 ± 0.28[c]
T2	49.56 ± 0.27[c]	42.27 ± 0.34[c]	32.66 ± 0.30[d]
T3	50.92 ± 0.45[b]	44.45 ± 0.44[b]	35.56 ± 0.39[b]
T4	53.46 ± 0.89[a]	46.35 ± 0.46[a]	38.19 ± 0.38[a]
T5	30.36 ± 0.25[d]	24.23 ± 0.60[e]	15.88 ± 0.33[f]
T6	31.17 ± 0.44[d]	25.81 ± 0.43[d]	17.32 ± 0.17[e]

Values are Means ± Standard Deviations.
[a-f]The means bearing the different letters in each column are significantly different ($P < 0.05$).

The vitamin C content got reduced because of the processing (Tables 4.1 and 4.4). The comparative analysis revealed that the vitamin C contents were found to be got reduced further during the storage periods in the cases of all the six treatments and the values were lower than the bench mark value obtained from the present study i.e. 115.71mg/100g.

On the 0 day of storage, there was notable disparities ($P < 0.05$) among the six treatments (Table 4.4). The variation was as low as 30.36 (T5) to as high as 53.46mg/100g (T4). Such a wide range was probably due to the fact that the two treatments viz. T5 and T6 had lots of moisture on account of the three reasons as noted in the section 4.5 earlier. Oppositely, the four treatments i.e. T1 to T4 had the high values ranging from 49.43 to only 53.46mg/ 100g and such high values with the minimum range was probably due to the fact that in those four cases, only dry fruits were used to have the powder. Again, there was the least variation between T5 and T6 (30.36 - 31.17mg/100g) where fresh fruits with water was used to have the paste.

On the 30th day of storage, there was significant difference ($P < 0.05$) among the six treatments. The variation was as low as 24.23 (T5) to as high as 46.35mg/100g (T4). There was low vitamin C content than the case of 0 day of storage. In addition, there was also a similar and gradual fall in the vitamin C contents in all the six treatments than their 0 day of storage.

On the 60th day of storage, there was also notable disparities ($P < 0.05$) among the six treatments judged. The variation was as low as 15.88 (T5) to as high as 38.19mg/100g (T4). So, the treatment T4 was best in terms of the retention of the highest amount of vitamin C. There were also low vitamin C contents than both the cases of 0 and 30th day of storages. In addition, there was also further identical and gradual fall in the vitamin C contents in all the treatments.

The fall in the vitamin C contents was quite expected as a number of studies strongly support that ascorbic acid is highly sensitive to heat (Raja *et al*., 2017; Gupta *et al*., 2013; Sarker *et al*., 2012). The loss of ascorbic acid in this study may be due to the prolong exposure of the chilli fruits for sun-drying (T1 - T4). The variation in vitamin C contents among the treatments may further occur due to difference in oxidation, container, storage environment etc.

Furthermore, the vitamin C contents of green chilli powder ranged from 49.43 - 53.46, 42.27 - 46.34 and 33.39 - 38.19mg/100g on the 0 day, the 30th and the 60th day after storage, respectively. The values of those findings are lower than the results obtained by Sharma *et al.* (2014) (47.75mg/100g), Toontom *et al.* (2012) (53.19mg/100gm) and Sarker *et al.* (2012) who obtained 59 - 67mg/100gm of dried green chilli powder. Such variations could be due to drying methods, varietal traits, oxidation etc.

Another vital observation is that the three treatments having pedicels intact with the fruits (T1, T2 and T5) had low vitamin C contents than their corresponding treatments where pedicels were detached from the fruits (T3, T4 and T6). This may happen due to the fact that fruits were rich in vitamin C, not the pedicels.

4.7 Sensory evaluation of the powder and the paste stored up to 60days

4.7.1 Evaluation for the colour

On the 0 day of storage, there was significant difference ($P < 0.05$) among the six treatments (Table 4.5). The variation was from 7.30 (T1) to 8.30 (T2). However, T2, T3 and T6 were statistically identical (8.30, 8.10 and 8.10) while T1, T4 and T5 were also statistically parallel to one another (7.30, 7.50 and 7.70). In contrast, T2 had the top score among the four powder treatments while T6 between the two paste treatments as well.

On the 60th day of storage, there was also notable disparities ($P < 0.05$) among the six treatments. The variation was from 6.50 (T1) to 7.70 (T2). However, T2, T3 and T6 were statistically identical (7.70, 7.50 and 7.20) while T3, T4, T5 and T6 were statistically parallel to one another (7.50, 7.10, 7.10 and 7.20). In addition, there was also further identical and gradual fall in the score from the 0 day to the 60th day. Oppositely, T2 topped the list among the four powder treatments while T6 between the two paste treatments.

The fall in the score for the colour from the 0 to the 60th day may be a common event as colour usually becomes dull due to oxidation and other chemical reactions, storage environment etc.

4.7.2 Evaluation for the flavour

On the 0 day of storage, there was significant difference ($P < 0.05$) among the six treatments (Table 4.5). The variation was between 7.10 (T1) to 8.20 (T2). However, T2, T3 and T6 were statistically identical (8.20, 7.90 and 7.90) while T1, T4 and T5 were statistically parallel to one another (7.10, 7.40 and 7.50). Oppositely, T2 had the highest score among the four powder treatments while T6 between the two paste treatments.

On the 60th day of storage, there was notable disparities too ($P < 0.05$) among the six treatments. The variation was 6.10 (T5) to 7.40 (T2). But T2 and T3 were statistically at per (7.40 and 7.10) while T1, T4, T5 and T6 were statistically parallel to one another (6.40, 6.30, 6.10 and 6.50). In addition, there was also further somewhat identical and gradual fall in the score for the sensory evaluation of the flavour of the products from the 0 day to the 60th day. Again, T2 had the highest score among the four powder treatments while T6 between the two paste treatments.

The fall in the score for the flavour of the products from the 0 day to the 60^{th} day may be a usual phenomenon as flavour commonly disappears and becomes less due to the volatilization of some essential oils followed by various reactions etc.

4.7.3 Evaluation for the texture

On the 0 day of storage, there was remarkable difference ($P < 0.05$) among the six treatments (Table 4.5). The variation was 7.10 (T1) to 8.20 (T2). Nonetheless, T2, T3 and T6 were statistically identical (8.20, 7.80 and 7.90) while T1, T4 and T5 were statistically parallel to one another (7.10, 7.20 and 7.50). But T2 had the highest value among the four powder treatments while T6 between the two paste treatments compared.

On the 60^{th} day of the storage, there was also notable disparities ($P < 0.05$) among the six treatments. The variation was 6.50 (T1) to 7.70 (T2). Nevertheless, T2 and T6 were statistically comparable (7.70 and 7.20) while T3, T4 and T5 were statistically parallel to one another (7.10, 6.60 and 6.90). Again, there was also further identical and gradual fall in the score from the 0 day to the 60^{th} day. Once again, T2 had the top most value among the four powder treatments while T6 between the two paste treatments.

The fall in the value of the sensory evaluation of the texture from the 0 day to the 60^{th} day may be a typical event due to chemical reactions, storage environment etc.

4.7.4 Evaluation for the overall acceptability

On the 0 day of the storage, there was significant variance ($P < 0.05$) among the six treatments (Table 4.5). The variation was 7.17 (T1) to 8.23 (T2). But T2 and T6 were statistically comparable (8.23 and 7.97) while T1 and T4 were statistically parallel to one another (7.17 and 7.37). Like other cases, T2 scored the top among the four powder treatments while T6 between the two paste treatments.

On the 60^{th} day of the storage, there was also notable disparities ($P < 0.05$) among the six treatments. The variation was 6.47 (T1) to 7.60 (T2). However, T2 and T6 were statistically similar (7.60 and 6.97) while T1, T4 and T5 were statistically parallel to one another (6.47, 6.67 and 6.70). In addition to those, there was also further identical and gradual fall in the score from the 0 day to the 60^{th} day. Moreover, T2 had the top score among the four powder treatments while T6 between the two paste treatments.

The fall in the sensory evaluation of the overall acceptability of the products from the 0 day to the 60^{th} day may be a usual issue as occurred due to chemical reactions, storage environment etc.

Table 4.5 Changes in the sensory attributes of the powder and the paste of the green chilli fruits variety Bogra Local during their storage up to 60 days

Treatment	Colour		Flavour		Texture		Overall acceptability	
	Storage period (Day)		Storage period (Day)		Storage period (Day)		Storage period (Day)	
	0	60th	0	60th	0	60th	0	60th
T1	7.30 ± 0.48[c]	6.50 ± 0.70[c]	7.10 ± 0.56[c]	6.40 ± 0.52[b]	7.10 ± 0.56[c]	6.50 ± 0.70[c]	7.17 ± 0.36[d]	6.47 ± 0.39[d]
T2	8.30 ± 0.48[a]	7.70 ± 0.67[a]	8.20 ± 0.42[a]	7.40 ± 0.52[a]	8.20 ± 0.42[a]	7.70 ± 0.67[a]	8.23 ± 0.16[a]	7.60 ± 0.38[a]
T3	8.10 ± 0.56[ab]	7.50 ± 0.70[ab]	7.90 ± 0.56[ab]	7.10 ± 0.57[a]	7.80 ± 0.68[ab]	7.10 ± 0.57[abc]	7.93 ± 0.44[b]	7.23 ± 0.50[b]
T4	7.50 ± 0.52[c]	7.10 ± 0.57[b]	7.40 ± 0.51[bc]	6.30 ± 0.48[b]	7.20 ± 0.63[c]	6.60 ± 0.69[bc]	7.37 ± 0.24[cd]	6.67 ± 0.42[cd]
T5	7.70 ± 0.67[bc]	7.10 ± 0.32[b]	7.50 ± 0.70[bc]	6.10 ± 0.32[b]	7.50 ± 0.70[bc]	6.90 ± 0.74[bc]	7.57 ± 0.22[c]	6.70 ± 0.25[cd]
T6	8.10 ± 0.56[ab]	7.20 ± 0.42[ab]	7.90 ± 0.56[ab]	6.50 ± 0.53[b]	7.90 ± 0.56[ab]	7.20 ± 0.42[ab]	7.97 ± 0.29[ab]	6.97 ±0.19[ab]

Values are Means ± Standard Deviations.

[a-d]The means bearing the different letters in each column are significantly different ($P < 0.05$).

CHAPTER V

SUMMARY AND CONCLUSIONS

An investigation was carried to know they effects of pretreatments on yield and quality of green chili powder and paste at the Laboratory, Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University, Dinajpur from April to June, 2018 with the green chilli fruits of the variety Bogra Local having three objectives: (i) to develop techniques for preserving green chilli in the forms of powder and paste, (ii) to assess the quality of those powder and paste during their storage, and finally (iii) to find out suitable techniques to preserve their quality in store. The six treatments (first four for making powder and last two for preparing paste) compared in the completely randomized design replicated four times were: T1- green chilli fruits with intact pedicels, cut longitudinally, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T2- green chilli fruits with intact pedicels, cut longitudinally, sliced, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T3- green chilli fruits without pedicels, cut longitudinally, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T4- green chilli fruits without pedicels, cut longitudinally, sliced, treated with 0.01% KMS solution, rinsed, sundried and made into powder; T5- green chilli fruits with intact pedicels, treated with 0.01% KMS solution, slight water was added and made into paste, and T6- green chilli fruits without pedicels, treated with 0.01% KMS solution, slight water was added and made into paste.

Data for these nine traits were taken: (i) ratio of the green chilli fruits to the powder, (ii) ratio of the green chilli fruits to the paste, (iii) moisture content, (iv) vitamin C content, (v) recovery of the powder and paste from the chilli fruits, (vi) storage quality of the stored products for: (a) colour, (b) flavour (c) texture, and (d) overall acceptability.

After preparing powder and paste, those were divided into three parts and stored for 0, 30 and the 60days to study their storage quality for both the moisture and vitamin C contents. But the four sensory traits studied on the 0 and the 60th day of storage were: colour, flavour, texture and overall acceptability.

The results clarified that the green chilli fruits had initially 86.6% moisture and 115.71mg/100g vitamin C contents. The % higher recovery of powder was found from T3 (11.0) compare to the rest three treatments (as T1, T2 and T4 yielded 8.8, 8.4 and 10.0%, respectively) while the recovery of paste was much higher from 135-140%.

The moisture contents of all the products increased little bit from the 0 day up to the final/ 60th day as the ranges were from 4.08 - 5.25 to 4.33 - 6.68 and 87.08 - 87.35 to 92.39 - 93.39%, in T3 - T4 and T5 - T6, respectively.

But in all the cases, the vitamin C contents decreased much from the 0 day of processing up to the 60th day. Still, the highest amount was noted in T4 (38.19) and T6 (17.32mg /100g) among the powder and the paste forms, respectively.

Finally, the sensory test indicated a fairly good physical appearance in terms of all the four traits: colour (6.50 - 7.70), flavour (6.40 - 7.40), texture (6.50 - 7.70) and overall acceptability (6.47 - 7.60) up to the 60th under ordinary temperature just with the use of the very well-known safe preservative i.e. KMS at a very low level of 0.01% solution.

Hence, from the present findings, the following conclusions can be highlighted:

a) The maximum powder and the paste yields were in T3 (11.0) and T5 (140.0) for the powder and the paste, respectively.
b) All the four treatments (T1 to T4) of powder had the moisture contents <10%, indicating that their shelf-life was stable up to the storage of 60 days in HDPB.
c) The maximum amount of vitamin C was retained in T4 (38.19) among the powder while T6 (17.32mg/100g) among the paste, and finally
d) All the six treatments had notable statuses in terms of sensory evaluation test (6.50 - 7.70 for the colour, 6.10 - 7.40 for the flavour, 6.50 - 7.70 for the texture and 6.47 - 7.60 for the overall acceptability) in case of both the powder and the paste forms).

However, the study paved further ways to work with other varieties, other forms of treatments (whole fruits with pedicel and whole fruits without pedicel), storage period up to one year, various bagging materials including oxygen and moisture free conditions, microbial conditions for hygienic purposes, several packing sizes for small, medium and large families as well as large scale uses (i.e. social functions) etc. to develop new and more sustainable technologies to preserve green chilli powder and paste with adequate nutritional quality and value addition too.

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