Studies on the Extension of Shelf life of Selected Type of Mangos

by

Md. Mizanur Murshed
01726-189011

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Philosophy in the Department of Chemistry

Khulna University of Engineering & Technology

Khulna-9203, Bangladesh

November, 2015

Declaration

This is to certify that the thesis work entitled "**Studies on the Extension of Shelf life of Selected Type of Mangos**" has been carried out by Md. Mizanur Murshed in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

27.11.15

Signature of Supervisor

Professor Dr. Mohammad Hasan Morshed

Department of Chemistry, KUET

Md. Mizanur Murshed 27.11.15

Signature of Candidate

Md. Mizanur Murshed

Roll No.1253501

Approval

This is to certify that the thesis work submitted by **Md. Mizanur Murshed** entitled ***"Studies on the Extension of Shelf Life of Selected Type of Mangos."*** has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Philosophy in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh in November 2015.

BOARD OF EXAMINERS

1. 27.11.15 — Chairman (Supervisor)
   Dr. Mohammad Hasan Morshed
   Professor
   Department of Chemistry
   Khulna University of Engineering & Technology
   Khulna-9203, Bangladesh.

2. 27.11.15 — Member
   Head
   Department of Chemistry
   Khulna University of Engineering & Technology
   Khulna-9203, Bangladesh.

3. — Member
   Prof. Dr. Mohammad Abu Yousuf
   Department of Chemistry
   Khulna University of Engineering & Technology
   Khulna-9203, Bangladesh.

4. 27.11.15 — Member
   Prof. Dr. Md. Abdul Motin
   Department of Chemistry
   Khulna University of Engineering & Technology
   Khulna-9203, Bangladesh.

5. Islam 27.11.15 — Member (External)
   Prof. Dr. Md. Azizul Islam
   Department of Chemistry
   University of Rajshahi.

ACKNOWLEDGEMENT

At the outset, all praise and gratitude to the Almighty Allah for his infinite mercy bestowed on me in carrying out the research work.

I would like to express my best indebtedness and deepest thanks to my honorable supervisor **Dr. Mohammad Hasan Morshed,** Professor, Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh, for his proper guidance, co-operation, invaluable suggestions and constant encouragement throughout this research work.

I am pleased to express my gratitude to the departmental Head Professor **Dr. Md. Abdul Motin,** for providing me necessary laboratory facilities and proper guidance for the research.

I am highly grateful and greatly indebted to **Dr. Md. Ibrahim**, Principal Scientific Officer, BCSIR Laboratories, Rajshahi, Bangladesh, for their constant supervision, expert guidance, enthusiastic encouragement and never-ending inspiration throughout the entire period of my research work as well as to prepare this dissertation.

I am also extremely thankful to the **Director**, BCSIR Laboratories, Rajshahi, Bangladesh, for his kind permission of Lab facilities.

I should take this opportunity to express my sincere thanks to Professor **Dr. Mohammad Abu Yousuf,** Department of Chemistry, Khulna University of Engineering & Technology, for his encouragement and co-operation throughout this research work.

I am also obliged all **teachers** of this department for their valuable advice and moral support. I am also expressing my thanks to all the **stuffs** of this department.

I wish to express my heartful obligation to my beloved and respected **mother**, **Sisters**, **my wife** and **daughters** for their moral and financial support, enthusiastic inspiration, constant encouragement and never ending affection in my education.

Lastly I also express my heartfelt thanks to all my friends and class fellows specially **Md. Arifuzzaman Khondokar**, **Md. Mohasin Ali** and **Md. Abdur Rahim.** All of them helped me according to their ability.

Md. Mizanur Murshed

Abstract

The application of different types of cost effective preservatives such as tetracycline, sodium benzoate, acetic acid and glycerine at various concentrations for the extension of shelf lives of Himsagar and Langra mangoes were studied. The physical characters such as appearance, colour, flavour, taste and texture of treated mango were more attractive than those of control one. The shelf life of treated mango was prolonged significantly as compared to that of control one. The weight loss control capacity of preservatives treated mangoes was higher than that from control at 500 ppm of tetracycline, 80 ppm of sodium benzoate and 100 ppm of acetic acid for Himsagar mango and 10 ppm of tetracycline, 100 ppm of sodium benzoate and 100 ppm of acetic acid for Langra cultivar. The superior treatment tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm of Himsagar cultivar reduced the physiological loss in weight 15.79% to 33.62% with respect to control at 7^{th} day. But at 8^{th} day, the treatments, tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm reduced the physiological loss in weight 35.34% to 40.33% with respect to control mango. On the other hand the superior treatments tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm of Langra mango reduced the physiological loss in weight 17.31% to 29.23% with respect to control at 8^{th} day. The treatments, tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm reduced the physiological loss in weight 31.65% to 41.53% with respect to control mango, cultivar of Langra at the 9^{th} day. The efficiency of glycerine as preservative of Himsagar and Langra mango was not more effective than the other preservatives. The nutritional qualities of mango were also affected remarkably after treatment with preservatives. At the last edible stage, chemical analysis of mango pulp of preservatives treated Himsagar mango at tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm showed higher pH (5.56, 5.73 and 5.22), TSS (15%, 16% and 18%), total sugar (22.24, 23.53 and 23.30 g/100g), iron (6.7327, 2.5959 and 1.6789 mg/100g), vitamin C (20.05, 21.61 and 20.35 mg/100g) and protein (1.53%, 0.60% and 2.90%) in comparison to control mango (pH = 5.19, TSS = 10%, total sugar = 18.60 g/100g, iron = 0.7218 mg/100g, vitamin C = 19.20

mg/100g and protein = 0.57%). The treatments, tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm showed higher pH (5.19, 5.21 and 5.25), TSS (16%, 14% and 17%), total sugar (11.31, 12.42 and 11.38 g/100g), iron (3.3852, 3.3079 and 4.9801 mg/100g), vitamin C (17.32, 17.81 and 18.09 mg/100g) and protein (2.35%, 3.22% and 1.85%) for cultivar of Langra in comparison to control mango (pH = 5.19, TSS = 10%, total sugar = 9.04 g/100g, iron = 0.7118 mg/100g, vitamin C = 16.21 mg/100g and protein = 0.55%). In comparison to control mango it is evident that the preservatives treated mangoes might be in superior quality as it contains higher vitamins, total soluble solids, total sugar, protein, iron and pH than those of control.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

Introduction

1.1 General

The mango (*Mangifera indica* Linn.) is a juicy stone fruit belonging to the genus *Mangifera*, consisting of numerous tropical fruiting trees, cultivated mostly for edible fruit. The majority of these species are found in nature as wild mangoes. The mango is the principal cash fruit crop of Rajshahi region [1] and it is one of the most important and valuable fruit of Bangladesh. It is also certainly one of the highly delicious and esteemed fruit of the world. Mango is a luscious and nutritious fruit and an excellent source of beta-carotene (Pro-vitamin A), essential minerals, vitamin C, carbohydrate and energy in human nutrition [2]. Fresh mango fruit is considered as a "king of fruit" in Bangladesh and is appreciated as the choicest of indigenous fruits by millions of people [3]. Mangoes are still judged as luxurious and expensive items of the markets of many industrialized countries. It is extensively cultivated in Bangladesh, India, Pakistan, Philippines, Thailand, Sri Lanka, Malaysia, Israel, Africa, some parts of Australia and America. Mango is generally produced once in a year while many of commercial varieties are biennial in bearer. In our country, mangoes are obtained from the month of April-May to July-August.

1.2 Origin

Mangoes have been cultivated in South Asia for thousands of years and reached East Asia between the fifth and fourth centuries. The 14th-century Moroccan traveler Ibn Battuta reported it at Mogadishu. Cultivation came later to Brazil, the West Indies and Mexico, where an appropriate climate allows its growth[4].

The mango belongs to the family *Anacardiaceae*. It has been cultivated for more than 4000 years as described [5]. According to him originated in South Asia or Malayan Archipelago. Popnoe [6] mentioned that it probably originated in Eastern India, Assam and Burma or further in the Malayan region. Mukherjee [7] reported that the genus *Mangifera* originated in Burma, Siam, Indo-china and the Malayan Peninsula; but the

mango itself had its origin in the Assam-Burma region which includes the area what is now Bangladesh. The top ten places of origin of mango are shown in Figure 1.1. The wild mangoes, particularly, *M. sylvatica Roxby*, are still found in the Chittagong Hill Tracts of Bangladesh [8]. Vavilov [9] had also the same opinion that the mango was originated in the Indo-Burma region. Bangladesh is proud to be the home of mango, one of the most important fruits of the world.

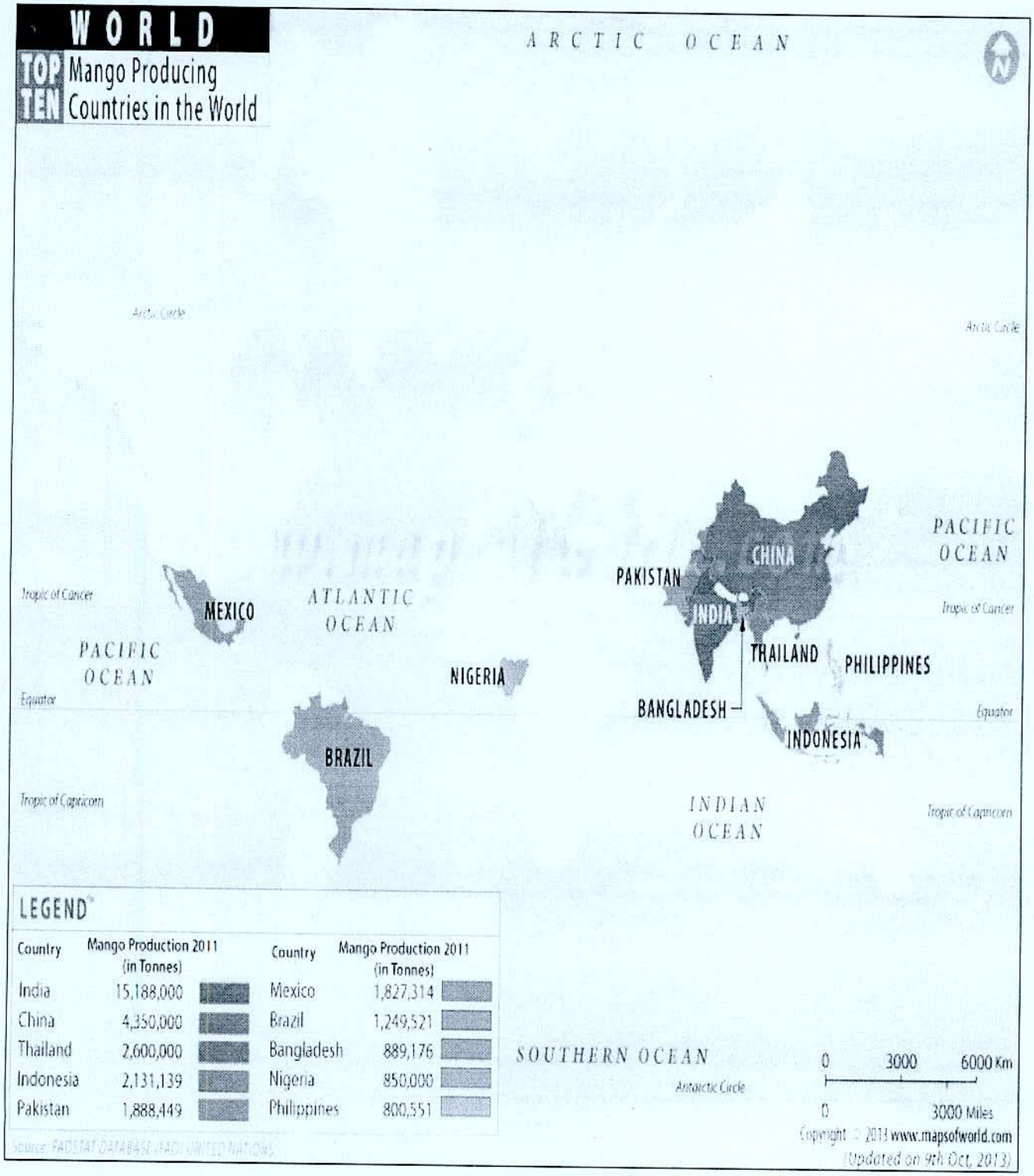


Figure 1.1: The top ten places of origin of mango.

1.3 Species varieties

Vegetative propagation which started 400 years back in India has helped to perpetuate outstanding chance seedlings. However, names of mango varieties remained ever confusing. The same variety has assumed different names in different places. This is further aggravated due to the fact that a variety can't be identified by vegetative characters alone. A variety introduced from one region to another may not behave the same way. It is reported that Langrage and Dusehri of Uttar Pradesh of India grown in Madras of the same country did not show resemblance to the original parent in respect of flavour, size and other characteristics [10]. On the other hand, if there is a search for high yielding, disease resistant, regular bearing varieties all desirable characters may not be found in one variety. However, all desirable characters may be combined in a variety through a systematic hybridization programme. So there is need for characterization of existing varieties.

Twelfth International Horticultural congress held at Berlin in 1938 recognized the importance of description and classification of varieties as a fundamental aspect of fruit research. It was affirmed at the Indian Horticultural Workers Conference held in New Delhi in 1947. Watt [11] was the earliest in describing mango using scientific terminology. Subsequently Maries [12] described 500 varieties of Indian mango. Woodhouse [13] described 40 mango varieties of Bihar while Burns & Prayag [14] described 89 varieties of Bombay Presidency. Popnoe [15] described 300 varieties of mango of all parts of the world. Sturrock and Wolfe [16] described 38 mango varieties of florida based on fruit characters only. All the workers did not include vegetative characters of varieties in their description. However, Mukherjee [17] who described 72 varieties of Bengal, Bihar and Uttar Pradesh while Naik and Gangolly [18] who described 335 varieties of South India used vegetative characters as well.

The cultivated mangoes in different regions of the world belong to different species but the mango varieties of Bangladesh belong to *Mangifera indica* L. The mango varieties of Philippines, Thailand and Indonesia are poly-embryonic. However, the mango varieties of Bangladesh are mono-embryonic and cross pollinated. The number of quality mango varieties cultivated in Bangladesh are not many. It is estimated to be around 250.

However, there are many more varieties which are not yet commercially important but maintained at family level [8]. The four main groups of mango varieties are the Indian, Floridian, Indonesian and Philippine [19]. Many varieties of mango are now available in Bangladesh. Of which important cultivars are listed below.

Table 1.1: Varieties of mango.

1.	Fazli	2.	Aswina
3.	Langra	4.	Khirsapat
5.	Gopalbhog	6.	Mohonbhog
7.	Misribhog	8.	Kishanbhog
9.	Rajbhog	10.	Baishaki
11.	Himsagar	12.	Lakhanbhog
13.	Lata bombai	14.	Ranipasand
15.	Surjapuri	16.	Kuapahari
17.	Ilsapeti	18.	Misrikanta
19.	Dilsad	20.	Amrita bhog.

1.4 Nutritional and medicinal value of mango

Importance of mango in human diet is well recognized. In fact, the juicy pulp, attractive colour, excellent flavour, delicious taste and nutritional value of mango pulp readily command attention of the consumers. Our diet is very poor and lack in essential constituents like vitamins and minerals. More than 80% of the people of Bangladesh are suffering from severe malnutrition. Malnutrition may be due to deficiency in proteins, vitamins and minerals. Mangoes are excellent source of vitamin like pro-vitamin A, vitamin B_1, vitamin B_2, folic acid and vitamin C, which help in the maintenance of proper health and resistance to diseases. It also provides minerals, such as iron (Fe), calcium (Ca) and phosphorus (P), the deficiency of which may lead to disturbance in the metabolism and can cause several ailments. In comparison with banana, papaya and jackfruit, which are generally considered to be above average in nutritional qualities and on the basis of nutrient content mango fruit might be superior to banana, papaya and jackfruit [20]. The nutritional composition of the above four fruits are shown in Table 1.2.

Table 1.2: A comparison on nutritional composition of four different types of fruits (100 g edible portion) [20]

Name of nutrient	Mango	Jackfruit	Banana	Papaya
Water (%)	88.6	78.0	62	88.4
Food energy (Cal/100g)	90.0	48.0	109	42
Total carbohydrate (%)	20	9.9	25	8.3
Protein (%)	1.0	1.8	1.2	1.9
Lipid (%)	0.7	0.1	0.8	0.2
Fibre (%)	0.7	0.2	0.4	0.8
Ash (%)	0.6	0.3	0.5	0.2
Calcium (mg/100g)	16	26	13	19
Phosphorus (mg/100g)	20	30	19	10
Iron (mg/100g)	1.3	0.5	0.9	0.5
Vitamin A (µg/100g)	8300	4700	500	8100
Vitamin B_2 (µg/100g)	0.07	0.15	0.05	0.03
Vitamin C (mg/100g)	90	21	24	42

Mango also supplies carbohydrates, proteins and fats. At initial stages of fruit development no systematic trend was observed in the sugar content, but toward the end of maturity, both reducing and non-reducing sugars were found to be increasing [21]. Leley [22] observed an increase from 1 to 13% in starch content in Alphonso mango during development. Mann [21] recorded a gradual decrease in acidity until harvest in Dashehari mangoes. Pathak and Sarada [23] reported that lipid content in pulp of five mango varieties ranged from 0.80-1.36% at harvest while pulp chlorophyll became negligible as the fruit approached maturity [24]. The total carotenoides and β-carotene remained very low initially and increased gradually as the fruits approached maturity and ripening but ascorbic acid gradually decreased as the fruits approached maturity [25]. Mango fruit contains 0.5-1% proteins on a fresh weight basis [26]. Tandon and Kalra [24] reported a decrease in the soluble protein content up to 44 days after fruit set, which increased again until 96 days.

Carotenoids are mainly responsible for the color of ripe mangoes. The composition of the carotenoides in Badami (Alphonso) mangoes were characterized by Subrayan and Cama [27] at three stages of maturity-unripe, partially ripe and fully ripe stages they found 14, 15 and 17 different carotenoids respectively. In fully ripe mangoes β-carotene constituted 50-64% of the total, with phylofluence (11.7%), quroxanthin (11.4%) cis-violananthin (7.08%) and phyloene (6.32%) comprising the other major carotenoids. The red blush in haden mango is attributed to the presence of the anthocyanin and peonidin-3-galactoside [28].

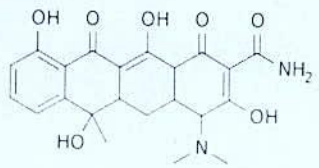
Many medicinal properties are also ascribed to mango. Dried flowers have curative properties for treating diarrhoea and chronic dysentry. The smoke burning leaves is believed to be efficacious against hiccough and several throat troubles. Bark yields mangiferine and tannin which are useful against diphtheria and rheumatism. The kernel is being given as medicine to persons suffering from asthma and diarrhoea. Barked and sugared pulp of unripe fruit is being considered very useful for cholera and plague patients.

The bark is a source of resins and gum. The gum of the tree and the resinous substance excluded from the stem end of the harvested fruits are mixed with lime juice and given in case of coetaneous affections and scabies.

1.5 Preservatives

1.5.1 Tetracycline

The first member of the group to be discovered is Chlortetracycline (Aureomycin) in the late 1940s by Benjamin Minge Duggar, a scientist employed by American Cyanamid - Lederle Laboratories,under the leadership of Yellapragada Subbarow, who derived the substance from a golden-colored, fungus-like, soil-dwelling bacterium named *Streptomyces aureofaciens* [29]. Oxytetracycline (Terramycin) was discovered shortly afterwards; it came from a similar soil bacterium named *Streptomyces rimosus* [30]. Robert Burns Woodward determined the structure of Oxytetracycline enabling. Conover to successfully produce tetracycline itself as a synthetic product [31].

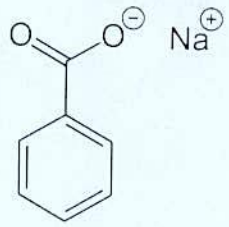


Stucture 1: The basic structure of tetracycline.

Tetracyclines are a group of broad-spectrum preservatives whose general usefulness has been reduced with the onset of preservative resistance. Despite this, they remain the treatment of choice for some specific indications [32].

1.5.2 Sodium Benzoate

Sodium benzoate has the chemical formula $NaC_7H_5O_2$. It is a widely used food preservative. It is the sodium salt of benzoic acid and exists in this form when dissolved in water. It can be produced by reacting sodium hydroxide with benzoic acid. Benzoic acid occurs naturally at low levels in prunes, greengage plums, cinnamon, ripe cloves and apples [33, 34]. It is bacteriostatic andfungistatic under acidic conditions. It is most widely used in acidic foods such as salad dressings (vinegar), carbonated drinks (carbonic acid), jams and fruit juices (citric acid), pickles (vinegar), and condiments. It is also used as a preservative in medicines and cosmetics [35, 36]. Concentration as a preservative is limited by the FDA in the U.S. to 0.1% by weight [37]. Sodium benzoate is also allowed as an animal food additive at up to 0.1%, according to AFCO's official publication [38].



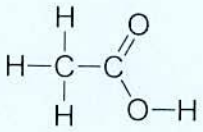
Stucture 2: The basic structure of sodium benzoate.

1.5.3 Acetic Acid

Acetic acid systematically named ethanoic acid is an organic compound with the chemical formula CH_3COOH (also written as CH_3CO_2H or $C_2H_4O_2$). It is a colourless liquid that when undiluted is also called *glacial acetic acid*. Vinegar is roughly 3-9% acetic acid by volume, making acetic acid the main component of vinegar apart from water. Acetic acid has a distinctive sour taste and pungent smell. Besides its production as household vinegar, it is mainly produced as a precursor to polyvinylacetate and cellulose acetate. Although it is classified as a weak acid, concentrated acetic acid is corrosive and can attack the skin [39-46]. Acetic acid is a chemical reagent for the production of chemical compounds. The largest single use of acetic acid is in the production of vinyl acetate monomer, closely followed by acetic anhydride and ester production. The volume of acetic acid used in vinegar is comparatively small [47, 48]. The major use of acetic acid is for the production of vinyl acetate monomer (VAM) [47]. The major esters of acetic acid are commonly used solvents for inks, paints and coatings. The esters include ethyl acetate, n-butyl acetate, isobutyl acetate, and propyl acetate [48]. Acetic anhydride is an acetylation agent. As such, its major application is for cellulose acetate, a synthetic textile also used for photographic film. Acetic anhydride is also a reagent for the production of heroin and other compounds [49]. Glacial acetic acid is an excellent polar protic solvent, as noted above. It is frequently used as a solvent for recrystallization to purify organic compounds [48].

Acetic acid is often used as a solvent for reactions involving carbocations, such as Friedel-Crafts alkylation [50]. Glacial acetic acid is used in analytical chemistry for the estimation of weakly alkaline substances such as organic amides. Glacial acetic acid is a much weaker base than water, so the amide behaves as a strong base in this medium. It then can be titrated using a solution in glacial acetic acid of a very strong acid, such as perchloric acid [51]. Diluted acetic acid is used in physical therapy using iontophoresis

[52]. Vinegar is typically 4-18% acetic acid by mass. The amount of acetic acid used as vinegar on a worldwide scale is not large, but is by far the oldest and best-known application [53].

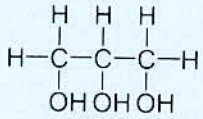


Stucture 3: The basic structure of acetic acid.

1.5.4 Glycerine

Glycerol (also called glycerine) is a simple polyol (sugar alcohol) compound. It is a colorless, odorless, viscous liquid that is widely used in pharmaceutical formulations. Glycerol has three hydroxyl groups that are responsible for its solubility in water and its hygroscopic nature. The glycerol backbone is central to all lipids known astriglycerides. Glycerol is sweet-tasting and is non-toxic [54-56]. In food and beverages, glycerol serves as a humectant, solvent, and sweetener and may help preserve foods. It is also used as filler in commercially prepared low-fat foods (e.g., cookies), and as a thickening agent in liqueurs. Glycerol and water are used to preserve certain types of plant leaves [57]. It is also recommended as an additive when using polyol sweeteners such as erythritol and xylitol which have a cooling effect, due to its heating effect in the mouth, if the cooling effect is not wanted [58]. Glycerol is used in medical and pharmaceutical and personal care preparations, mainly as a means of improving smoothness, providin glubrication and as a humectant. It is found in allergen immunotherapies, cough syrups, elixirs and expectorants, toothpaste, mouthwashes, skin care products, shaving cream, hair care products, soaps and water-based personal lubricants. Glycerol can be used as a laxative when introduced into the rectum in suppository or small-volume (2–10 mL) (enema) form; it irritates the anal mucosa and induces a hyperosmotic effect [59]. Taken orally (often mixed with fruit juice to reduce its sweet taste), glycerol can cause a rapid, temporary decrease in the internal pressure of the eye. This can be useful for the initial emergency treatment of severely elevated eye pressure [60]. When utilized in 'tincture' method extractions, specifically as a 10% solution, glycerol prevents tannins from precipitating in ethanol extracts of plants (tinctures). It is also used as an 'alcohol-free' alternative to ethanol as a solvent in preparing herbal extractions [61, 62]. Vegetable glycerine is a common component of

e-liquid, a solution used with electronic cigarettes that is heated with an atomizer to produce vapor in order to deliver flavors and optionally nicotine. Glycerol was historically used as an anti-freeze for automotive applications before being replaced by ethylene glycol, which has a lower freezing point. While the minimum freezing point of a glycerol-water mixture is higher than an ethylene glycol-water mixture, glycerol is not toxic and is being re-examined for use in automotive applications [63, 64]. Glycerol is used to produce nitroglycerin, which is an essential ingredient of various explosives such as dynamite, gelignite, and propellants like cordite. Allyl iodide, a chemical building block for polymers, preservatives, organometallic catalysts, and pharmaceuticals, can be synthesized by using elemental phosphorus and iodine on glycerol [65]. Glycerol is used by the film industry when filming scenes involving water in order to stop areas drying out too quickly [66].



Stucture 4: The basic structure of glycerine.

1.6 Aim of the Present Study

Mango is now recognized as one of the best fruits of all indigenous fruits. It is mostly available seasonal fruit in Bangladesh is liked by millions of people due to its excellent flavour, attractive fragrance, beautiful shades of colour, high nutritive value, delicious taste and also economic potentiality in fruit base crop [67-71]. Approximately 30-50% fruits go waste during postharvest handling, storage and ripening [72]. Among the fruits mango manifested high postharvest losses because of its high perishability and climacteric pattern of respiration. The marketability of this perishable fruit is closely linked with the development of suitable technology which reduces the loss of storage life.

The postharvest life of any fruit consists of ripening and senescence. After harvest, fruits undergo many physiological and biochemical changes during storage. Apart from those changes, microbial decay also contribute to postharvest losses during ripening and storage. The storage life of a fruit could be prolonged significantly through slowing down the process leading to ripening, and controlling the microbial decay.
The physico-chemical changes during ripening and storage need to be studied extensively to develop more effective technique(s) of prolonging economic storage life of mango. Nutritional and edible qualities of mango are affected by application of the post harvest treatments and also, by harvesting the fruits at various stages of maturity. Several authors [73-76] studied the postharvest losses and physico-chemical changes during ripening and storage of mango. But such studies are inadequate to explain the situation in our country.

This research includes the shelf life study and develop a technology that will delay the ripening process of the commercial varieties of Himsagar and Langra mango of Shatkhira and Rajshahi zone . The following are the objectives of the research work for carrying out the postharvest life of mango to enhance the storage life and to reduce the spoilage of mango as caused by various factors without changing the original fruit quality. The specific aims are:

1. to reduce the post harvest losses (spoilage) of Himsagar and Langra mango
2. to increase the shelf life of this mango
3. to retain the quality and characteristics of mango.

CHAPTER II

Literature Review

2.1 In which way mangoes are infected

Mangoes are infected by Xanthomonas campestris bacteria [77].

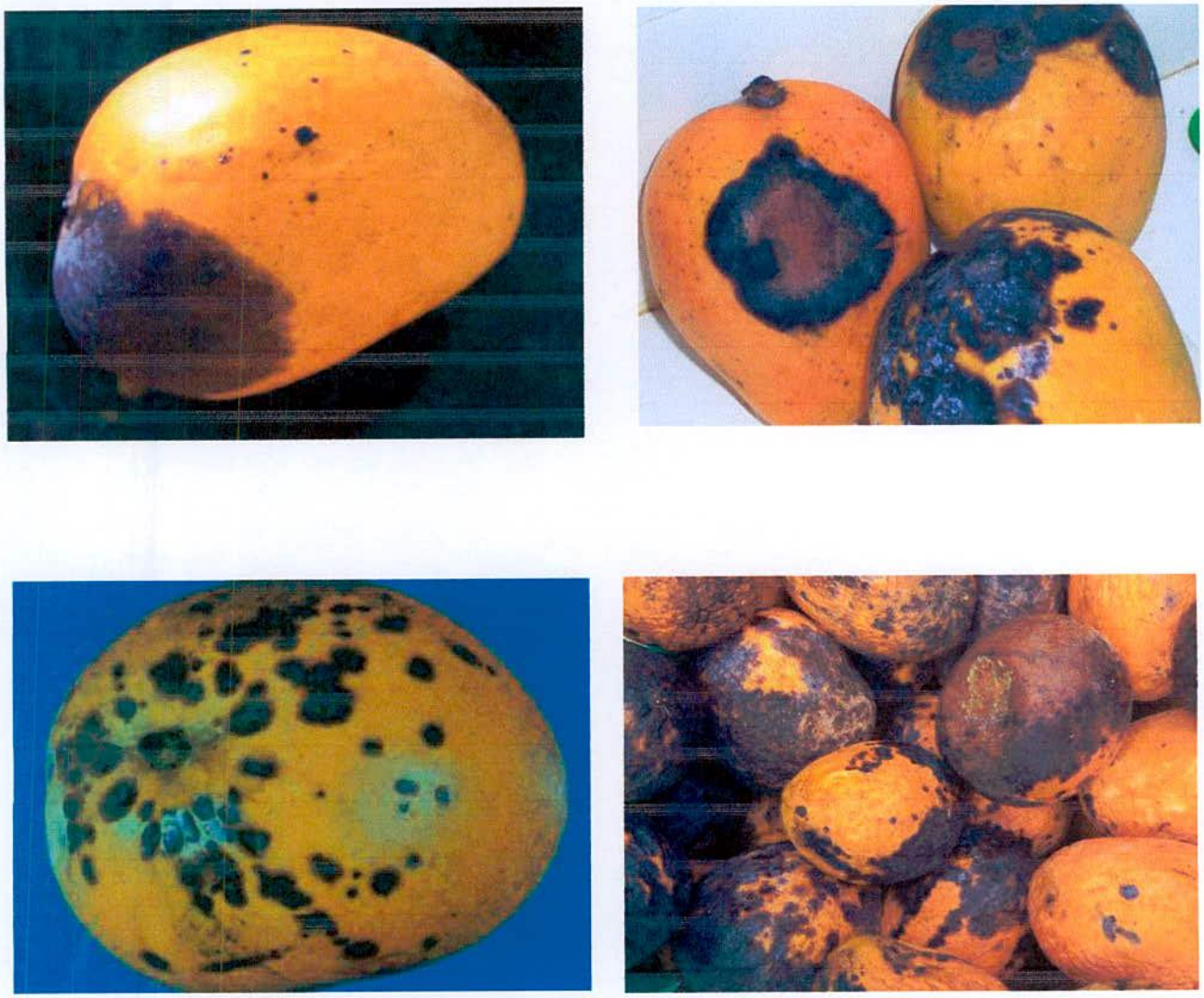


Figure 2.1: Some infected mangoes[78].

2.2 Effects of preservatives on the post harvest losses

Approximately 30 -50 % fruits go waste during post harvest handling, storage and ripening [79, 82]. Among the fruits mango manifested highest post harvest losses because of its high perish ability and climacteric pattern of its high perish ability and climatic pattern of this perishable fruit is closely linked with the development of suitable technology which reduces the losses at different stages of harvesting, packaging and storage. The storage life of any fruit consists of ripening and senescence. After harvest, fruits undergo many physiological and biochemical changes during storage. The storage life of fruits could be prolonged significantly through slowing down the process leading to ripening and controlling the microbial decay [80,81].

Quality mangoes are produced in north-western part of Bangladesh, of which about 35-38% post harvest losses are caused due to inefficient handling during its transportation, storage and marketing [83]. Hence the development of technologies for reducing post harvest losses is a necessary prerequisite for the promotion of the fruit industry. It is very important not only to produce more but also to save whatever is grown at production cost. The postharvest life of mango could also be increased remarkably using plant hormones [84].

2.3 Effects of preservatives on the improvement of quality

Mango is mostly available seasonal fruit in Bangladesh is liked by millions of people due to its excellent flavour, attractive fragrance, beautiful shades of colour, high nutritive value, delicious taste and also economic potentiality in fruit base crop (i.e. quality parameters) [70,71]. It is also a luscious and nutritious fruit and chief source of beta-carotene (pro-vitamin A), ascorbic acid (vitamin C), essential minerals (basically-calcium, phosphorus and iron), carbohydrate and energy in human nutrition [1, 67-69]. Quality fruits are important ingredients of human diet and also useful for processing, Quality mangoes are produced in north-western part of Bangladesh, of which about 35-38% post harvest losses are caused due to inefficient handling during its transportation, storage and marketing [83]. Hence the development of technologies for reducing post harvest losses is a necessary prerequisite for the promotion of the fruit industries in Bangladesh.

CHAPTER III

Methodology

3.1 Treatments and determination of shelf life

Freshly harvested uniformly ripe mango cultivar of Himsagar and Langra are collected from the experimental mango research garden of Shatkhira and Rajshahi zone, during May and June 2014. During the period of study the ambient temperature and relative humidity in the laboratory ranged between 30 - 35°C and 75 - 80%, respectively. Only sound and firm ripe 630 nos of Himsagar and 720 nos of Langra mangoes that are averagely uniform size, shape and colour were used in this experiment for each preservatives. All the preservatives were collected from local marcket.

The Himsagar mangoes were divided in 36 lots, containing 15 mangoes in each lot and the treatment were made by three different preservatives. Tetracycline, sodium benzoate and acitic acid in twelve concentrations (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 500 and 1000 ppm) were used in this experiment. There were two treatments on glycerine (1 drop once and 1 drop everyday) which had 2 Lots containing 20 mangoes in each lot. There were also one treatments this are dipped in water at room temperature which had 2 Lots containing 15 mangoes in each lot. There were also 2 Lots has taken as the control. So there were altogether 42 treatments including the control. The lots of mangoes under experiments were marked and designed. The lots of mangoes were dipped 10 minutes in three different preservatives solutions of (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 500 and 1000 ppm). The control were marked and designed and kept at room temperature (30-35°C) in identical condition.

The Langra mangoes were divided in 45 lots, containing 15 mangoes in each lot and the treatment were made by three different preservatives. Tetracycline, sodium benzoate and acitic acid in fifteen concentrations (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500 and 1000 ppm) were used in this experiment. There were also one treatments this are dipped in water at room temperature which had one Lots containing 15 mangoes in each lot. There were also 2 Lots has taken as the control. So there were altogether 48 treatments including the control. The lots of mangoes under experiments were marked and designed. The lots of mangoes were dipped 10 minutes in three different preservatives solutions of (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500 and 1000 ppm). The control were marked and designed and kept at room temperature (30-35°C) in identical condition.

Figure 3.1.1: BCSIR Laboratory, Rajshahi

Figure 3.1.2: Mango garden, Rajshahi

Figure 3.1.3: Mango garden, Satkhira

Figure 3.1.4 BCSIR Laboratory, Rajshahi

For determining the physiological weight losses, the initial weight was recorded just before the treatment. Subsequently, their weights were recorded daily and the loss in weight was expressed as the percentage over the initial weight. To determine the shelf life, all the lots were observed every day at 5 pm for all treatment.

3.2 Physical properties and chemical analysis

This study includes detailed nutrient analysis of commercially important cultivar of Himsagar and Langra mango. During post harvest period of control and preservatives treated mango. Freshly harvested mango for control and preservative treatment were collected from experimental mango research garden Rajshahi, Bangladesh. All the reagents used in the analysis were of analytical grade. Specifications of them are given below:

Chemicals	Producer
Tetracycline	Square Co. Ltd, Bangladesh
Glycerine	Square Co. Ltd, Bangladesh
Sodium Benzoate	E. MERCK, India
Acetic Acid	E. MERCK, India
Ethanol	E. MERCK, India
NaOH	E. MERCK, India
Buffer Tablet pH 7	BDH Chemicals, England
H_2SO_4	BDH Chemicals, England
DNS	BDH Chemicals, England
Rochelle salt	E. MERCK, India
$CuSO_4$ $5H_2O$	E. MERCK, India
Potasium Sulphate	E. MERCK, India
Potasium per Sulphate	E. MERCK, India
Potasium thio Cianite	E. MERCK, India

3.2.1 Determination of pH

Extraction of mango juice : About 1-2 g of mango pulp was taken in a mortar. The pulp was crushed thoroughly in a mortar with pestle and homogenized well, and then filtered through two layers of muslin cloth. The filtrate was then centrifuged for 10 min. at 3000 rpm and the clear supernatant was collected.

Standard buffer solution

pH 7.0 or 4.0 buffer tablet (BDH Chemicals Ltd. Poole England) was dissolved in distilled water and made up to the mark of 100 mL with distilled water.

Procedure

The electrode assembly of the pH meter was dipped into the standard buffer solution of pH 7.0 taken in a clear and dry beaker. The temperature correction knob was set to 28°C and the fine adjustment was made by asymmetry potentially knob to pH 7.0. After wash the electrode assembly was then dipped into a solution of standard pH 4.0 and adjusted to the required pH by fine asymmetry potentially knob. The electrode assembly was raised, washed with distilled water, rinsed off with juice of the cultivars and dipped into the juice of the mango pulp. The pH of the juice was noted.

3.2.2 Estimation of total titrable acidity

The total titrable acidity of mango pulp was determined by titrimetric method [85].

Reagents

Standard NaOH solution (0.1 N).

1% Phenolphthalein solution.

Extraction of mango pulp juice : The mango pulp juice was extracted by the procedure same as described previously.

Procedure

Mango pulp juice was taken in a conical flask. Two to three drops of phenolphthalein indicator was added and mixed thoroughly. It was then titrated immediately with 0.1N NaOH solution from a burette till a permanent pink colour was appeared. The volume of NaOH solution required for titration was noted. The percentage of total titrable acidity present in the mango pulp was determined using the formula given below.

Calculation

Amount of acidity in the mango pulp (g per 100 g of mango pulp)

$$= \frac{\text{Volume of alkali needed for titration} \times \text{Strength of alkali} \times \text{Eq. wt. of acid} \times 100}{\text{Weight of mango pulp} \times 1000}$$

3.2.3 Determination of total soluble solids (TSS)

The total soluble solids (TSS) content of mango pulp was directly determined from the percentage scale (0-90 %) of Kyowa hand refractometer [85]. A drop of juice squeezed from

control and preservatives treared mango pulp was placed on the prism of refractometer and percent of total soluble solids was obtained from driect reading.

3.2.4 Determination of total sugar

Total sugar content of mango pulp was determined colorimetrically by the anthrone method as described in Laboratory Manual in Biochemistry [86]. Anthrone reagent: The anthrone reagent was prepared by dissolving 2 g of anthrone in 1 liter of concentrated H_2SO_4

a) Standard glucose solution: A standard solution of glucose was prepared by dissolving 10 g of glucose in 100 mL of distilled water.

Extraction of sugar from mango pulp : Extraction of sugar from mango pulp was done following the method described by Loomis and Shull [87].

Four to six g of mango pulp were plunged into boiling ethyl alcohol and allowed to boil for 5-10 min (5 to 10 mL of alcohol was used for every g of mango pulp). The extract was cooled and crushed thoroughly in a mortar with a pestle. Then the extract was filtered through two layers of muslin cloth and re-extracted the ground tissue for three min in hot 80 per cent alcohol, using 2 to 3 mL of alcohol for every g of sample. This second extraction ensured complete removal of alcohol soluble substances. The extract was cooled and passed through muslin cloth. Both the extracts were filtered through Whatman No-41 filter paper.

The volume of the extract was evaporated to about $^1/_4{}^{th}$ the volume over a steam bath and cooled. This reduced volume of the extract was then transferred to a 100 mL volumetric flask and made up to the mark with distilled water. Then 1 mL of the diluted solution was taken into another 100 mL volumetric flask and made up to the mark with distilled water (working standard).

Procedure

Aliquot of 1 mL of the extract was pipetted into test tube and 4 mL of the anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on the top of each tube to prevent loss of water by evaporation. The test tubes were heated for 10 min in a boiling water bath and then cooled. A reagent blank was prepared by taking 1 mL of water and 4 mL of anthrone reagent in a tube and treated similarly. The absorbance of the blue green solution was measured at 625 nm using the blank.

The amount of total sugar content in mango pulp was calculated by constructing a calibration curve using glucose as standard.

A standard curve of glucose was prepared by taking 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1 mL of standard glucose solution in different test tubes containing 0.0, 10 μg, 20 μg, 40 μg, 60 μg, 80 μg and 100 μg of glucose respectively and made the volume upto 1.0 mL with distilled water. Then 4 mL of anthrone reagent was added to each test tube and mixed well. All these solutions were treated similarly as described above. The absorbance was measured at 625 nm using the blank containing 1 mL of water and 4 mL of anthrone reagent. The amount of total sugar was calculated from the standard curve of glucose (Figure 3.1). Finally, the percentage of total sugar present in the mango pulp was determined using the formula given below.

Calculation

$$\text{Amount of total sugar in the mango pulp (g per 100 g of mango pulp)} = \frac{\text{Amount of total sugar obtained}}{\text{Weight of mango pulp}} \times 100.$$

3.2.5 Determination of reducing sugar

Reducing sugar content of mango pulp was determined by dinitrosalicylic acid method [88].

Reagents

a) Dinitrosalicylic acid (DNS) reagent: simultaneously 1 g of DNS, 200 mg of crystalline phenol and 50 mg of sodium sulphite were placed in a beaker and mixed with 100 mL of 1% NaOH solution by stirring. If it is need to store then sodium sulphite must be added just before use.

b) 40% solution of Rochelle salt.

Extraction of reducing sugar from mango pulp

Reducing sugar extract from mango pulp was done by the procedure as described earlier.

Procedure

Aliquot of 3 mL of the extract was pipetted into test tubes and 3 mL of DNS reagent was added to each of this solution and mixed well. The test tubes were heated for 5 min in a boiling water

bath. After the color has developed 1 mL of 40% Rochelle salt was added when the contents of the tubes were still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 mL of water and 3 mL of DNS reagent in a tube and treated similarly. The absorbance of the solution was measured at 575 nm in a colorimeter. The amount of reducing sugar content in mango pulp was calculated by constructing a calibration curve using glucose as standard (Figure 3.2).

Calculation

Amount of reducing sugar in mango pulp (g per 100 g of mango pulp)

$$= \frac{\text{Amount of reducng sugar obtained}}{\text{Weight of mango pulp}} \times 100$$

3.2.6 Determination of non-reducing sugar

Non-reducing sugar was calculated from the following formula.

Non-reducing sugar = (% Total sugar - % reducing sugar)

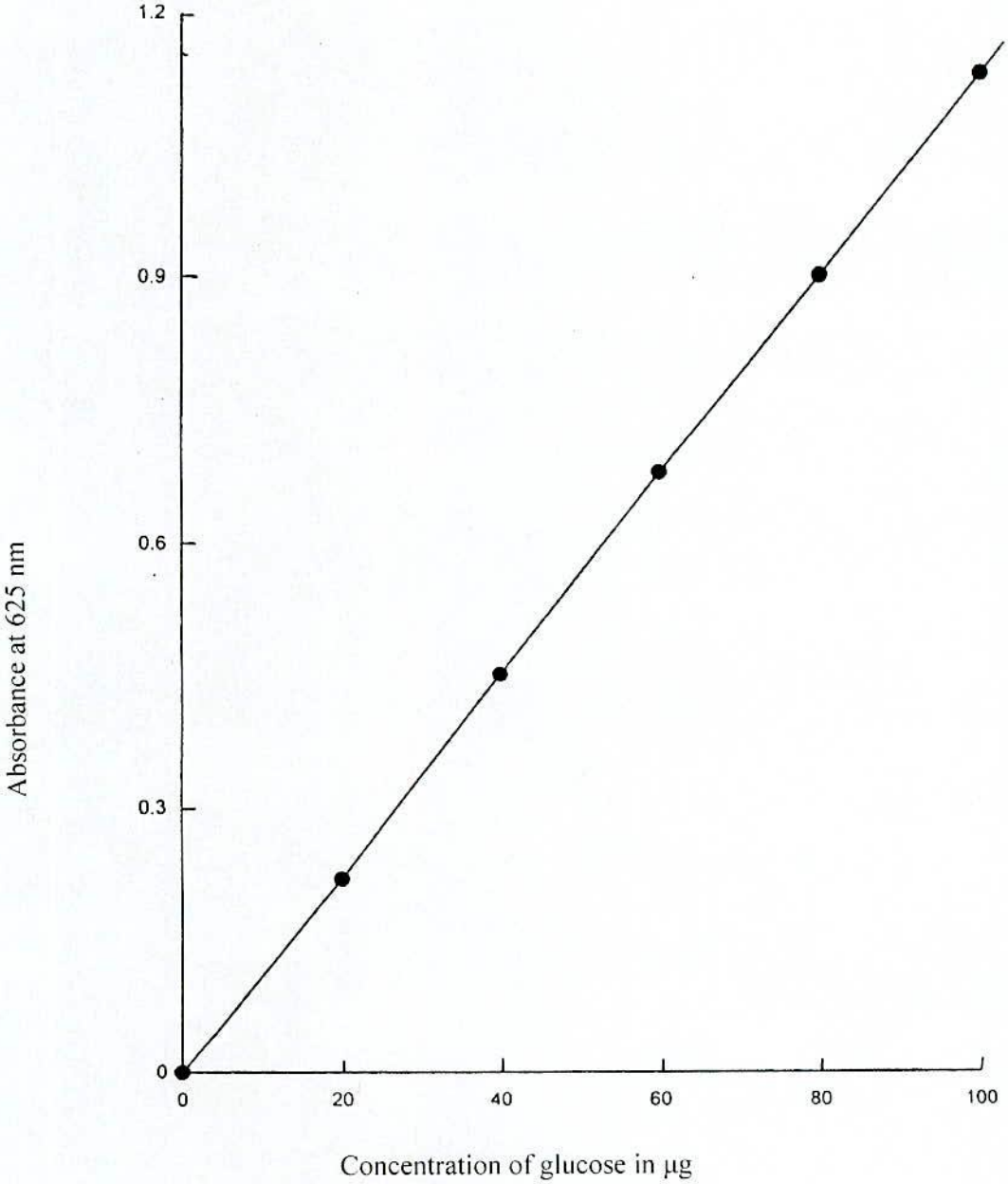


Figure 3.1: Standard curve of glucose for estimation of total sugar.

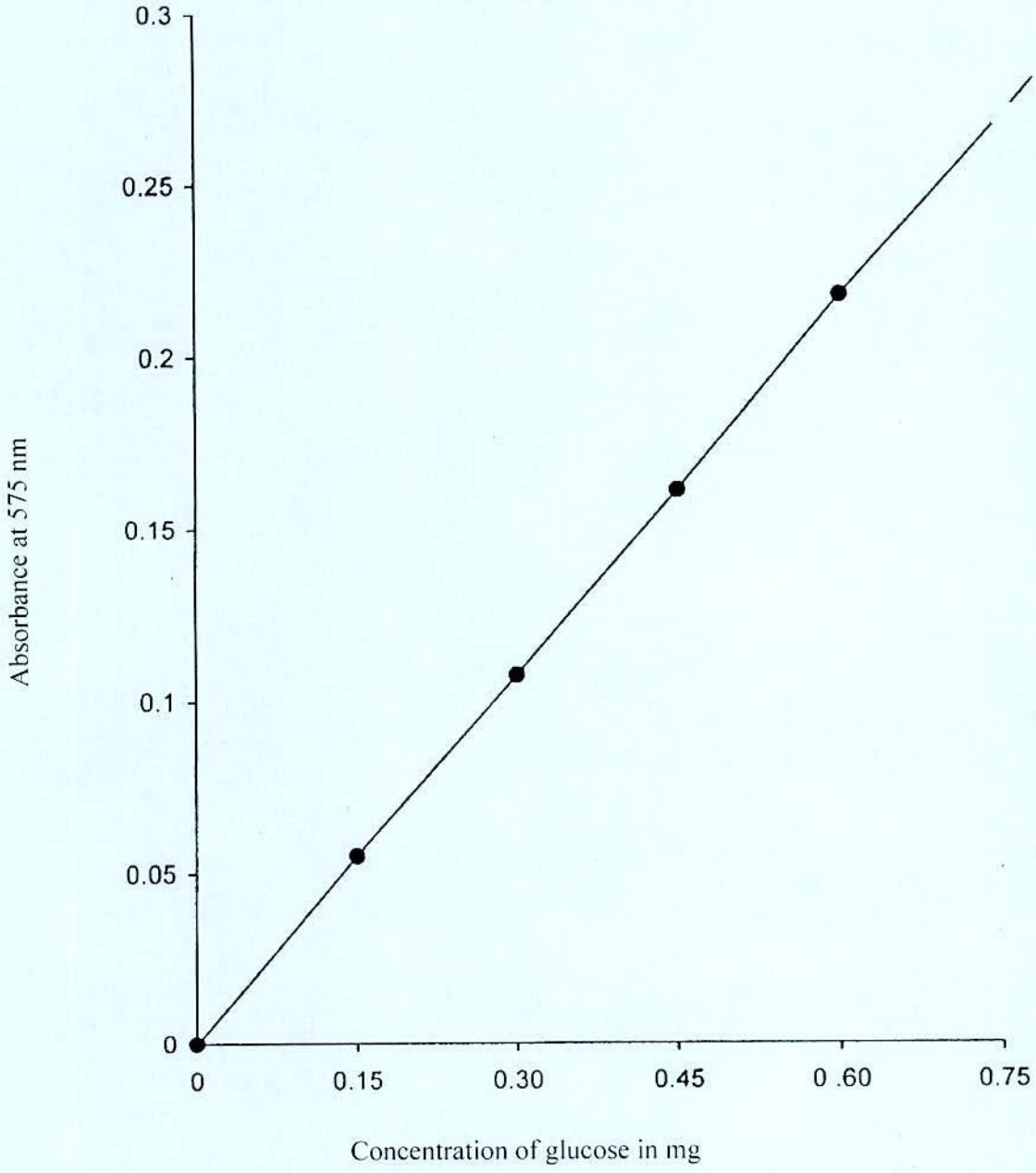


Figure 3.2: Standard curve of glucose for estimation of reducing sugar.

3.2.7 Estimation of ascorbic acid (vitamin C)

Ascorbic acid (vitamin C) of mango pulp was determined by the titrimetric method [89].

Reagents

a) Dye solution: 200 mg of 2,6-dichlorophenol indophenol and 210 mg of sodium bicarbonate were dissolved in distilled water and made up to 1000 mL. The solution was then filtered.

b) 3% Meta phosphoric acid reagent: 3 g of meta phosphoric acid was dissolved in 80 mL of acetic acid and made up to 100 mL with distilled water.

c) Standard ascorbic acid solution (0.1 mg/mL): 10 mg of pure ascorbic acid was dissolved in 3% meta phosphoric acid and made up to 100 mL with 3% meta phosphoric acid.

Procedure

10 mL of standard ascorbic acid solution was taken in a conical flask and titrated it with the dye solution.

Four to six g of mango pulp were cut into small pieces and homogenized well with 3% meta phosphoric acid (approximately 20 mL) and filtered it through double layer of muslin cloth. The filtrate was centrifuged at 3,000 rpm for 10 min. and the clear supernatant was titrated with 2,6-dichlorophenol indophenol solution. The amount of ascorbic acid present in the mango pulp was determined by comparing with the titration result of standard ascorbic acid solution.

Calculation

Amount of ascorbic acid in mango pulp (mg per 100 g of mango pulp)

$$= \frac{\text{Amount of ascorbic acid obtained}}{\text{Weight of mango pulp}} \times 100$$

3.2.8 Determination of total protein

Protein content of the treated and untreated mango pulp was determined by the method of Micro-Kjeldahl [90].

Reagents and equipments

a) Solid potassium sulphate

b) Concentrated sulfuric acid

c) 5% $CuSO_4.5H_2O$ in distilled water

d) 0.10N H_2SO_4 solution

e) Concentrated sodium hydroxide solution (5 N approximately)

f) Few quartz chips

g) Boric acid solution containing bromocresol green (receiving fluid): 10 g of boric acid was dissolved in hot water (about 250 mL) and cooled. 1 mL of 0.1% bromocresol green in alcohol was added and made upto 500 mL with distilled water.

h) Nitrogen determination apparatus according to Paranas-Wagner, made of JENA Glass-all connections with inter changeable ground joints.

(a) Digestion : Concentrated H_2SO_4 (6-8 mL), 1.0 g K_2SO_4 one to two drops of 5% $CuSO_4$ solution (catalyst) and some quartz chips were added (to avoid bumping) to 3-5 g of mango pulp in a Kjeldahl flask. The mixture was heated till it had become light green (2-3 hours).

(b) Collection of ammonia : The digestion was carried out in the steam distillation chamber of the nitrogen determination apparatus. The chamber is designated to act as a micro Kjeldahl flask and can be easily detached when needed. After completion of digestion the steam distillation chamber containing the digested mixture was fitted back to the nitrogen determination apparatus. Boric acid solution (15 mL) in a small flask was placed so that the tip of the condenser outlet dipped below the surface of the boric acid solution. Sufficient amount of concentrated sodium hydroxide solution (Approximately. 30-40 mL) was added to the digest in the chamber to neutralize the amount of acid present. Steam was generated from the steam-generating flask and the sample in the chamber was steam distilled until 20 mL of distillate was collected in the boric acid solution. The condenser outlet was then rinsed with little distilled water and the receiving flask was removed.

(c) Titrimetric examination of ammonia : The ammonia in the boric acid solution was titrated with 0.01N H_2SO_4 until the solution had been brought back to its original yellow green color. The titration was repeated with a control containing only 15 mL of boric acid solution diluted to approximately the final volume of the titrated sample. The volume of acid required was noted.

The nitrogen content was calculated using the formula given below.

1 mL of 0.01N $H_2SO_4 \equiv 140$ µg of nitrogen in NH_3.

Thus from the volume of standard H_2SO_4 used for titration, the amount of nitrogen in sample was calculated. The value multiplied by 6.25 give the approximate protein content of the sample used.

Calculation

Amount of protein in the mango pulp (g per 100 g of mango pulp) .

$$= \frac{\text{Amount of protein obtained}}{\text{Weight of mango pulp}} \times 100$$

3.2.9 Determination of iron

Iron content of mango pulp was determined by converting the iron to ferric form using oxidizing agents like potassium persulphate and treating thereafter with potassium thiocyanate to form the red ferric thiocyanate . The absorbances of the solutions were taken at 510 nm in a Coleman Junior 11 spectrophotometer [91].

Reagents

a) Conc. sulphuric acid
b) Saturated potassium persulphate
c) Potassium thiocyanate solution
d) Standard iron solution

Preparation of ash solution

1-2 g of mango pulp was placed in a weighed porcelain crucible (which was previously cleaned and heated to about 100°C, cooled and weighed). The crucible was placed in a muffle furnace for about 18 hrs at about 550°C. It was then cooled in a desiccator and weighed. To ensure completion of ashing, the crucible was again heated in the muffle furnace for half an hour, cooled and weighed again. This was repeated till two consecutive weights were the same and the ash was almost white in color [92]. The ash was moistened with a small amount of distilled water (0.5–1.0 mL) and then 5 mL of conc. HCl was added to it. The mixture was evaporated to dryness on a boiling water bath. Another 5 mL of conc. HCl was added again to the precipitate and the solution was evaporated to dryness as before. Then 4 mL of conc. HCl and a few mL of distilled water were added to the dry ash and the solution was warmed on a boiling water bath. The warmed solution was then filtered into a 100 mL volumetric flask using Whatman No-41 filter paper. After cooling the volume was made upto 100 mL with distilled water and suitable aliquot was used for the estimation of iron.

Procedure

Three different sets of experiments (Blank, Standard and Sample) were performed for the determination of iron. The following different solutions were taken in different 25 mL volumetric flask.

In each of the above volumetric flask , made the volume upto 15 mL with water. After mixing the solution, the absorbance of the pink-red coloured solution was measured at 480 nm in a colorimeter. The amount of iron present in the mango pulp was calculated by using the formula given below.

Calculation

Amount of iron in the mango pulp (mg per 100 g mango pulp)

$$= \frac{\text{OD of Sample} \times 0.1 \times \text{Total volume of ash solution} \times 100}{\text{OD of standard} \times 5 \times \text{Weight of sample taken for ashing}}$$

CHAPTER IV

Results and Discussion

4.1 Effects of preservatives on the shelf life of mango

It is seen from the table 4.1 to 4.6 that the shelf life of Himsagar mango was enhancing in different treatments of preservatives. The shelf life was longer (9 days) in 500 and 1000 ppm tetracycline, 80 ppm sodium benzoate and 10 and 100 ppm acetic acid treated fruits compared to control (8 days). It was found that the physiological loss in weight of all treated fruits were lower than that of control.

The table 4.7 to 4.11 that the shelf life of Langra mango was enhancing in different treatments of preservatives. The shelf life was longer (13 days) in 10 ppm tetracycline, 70 and 100 ppm sodium benzoate and 100 ppm acetic acid treated fruits compared to control (10 days). It was found that the physiological loss in weight of all treated fruits were lower than that of control.

The physiological loss in weight (PLW) of treated and control mango was determined after every day and the results were recorded in table 4.1 to 4.11. It was found that the physiological loss in weight of all sets of treated fruits were lower than that of control.

The loss in weight increased with increasing of storage period. There was a little weight loss in treated fruits compared to control. The superior treatment tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm of Himsagar reduced the physiological loss in weight 15.79% to 33.62% with respect to control at 7^{th} day. But at 8^{th} day the treatments tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm reduced the physiological loss in weight 35.34% to 40.33% with respect to control mango. On the other hand the superior treatments tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm of Langra reduced the physiological loss in weight 17.31% to 29.23% with respect to control at 8^{th} day. But at 9^{th} day the treatments tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm reduced the physiological loss in weight 31.65% to 41.53% with respect to control mango. However it was reported that the percent weight loss in fruits increases with increasing length of storage period regardless of method of ripening [93].

Table 4.1: Weight of tetracycline treated mango (%) at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
10 ppm	100	98.29	96.05	93.97	86.86	65.00	28.88	15.81	0
20 ppm	100	98.25	95.73	94.00	72.25	52.31	45.77	38.28	25.55
30 ppm	100	98.22	88.56	83.18	64.23	45.19	35.29	16.13	0
40 ppm	100	98.261	95.57	91.47	80.78	72.19	58.24	29.10	0
50 ppm	100	97.26	94.53	92.80	91.27	74.10	72.48	34.07	0
60 ppm	100	98.47	87.62	89.28	73.11	59.62	42.00	8.59	0
70 ppm	100	98.38	88.50	86.94	85.67	77.15	64.41	50.87	27.74
80 ppm	100	97.60	95.51	93.44	80.05	58.37	52.02	28.21	0
90 ppm	100	97.73	88.39	86.64	71.67	62.91	43.27	31.61	0
100 ppm	100	97.89	87.97	86.21	84.96	71.35	57.12	44.52	0
500 ppm	100	98.704	96.31	91.16	78.61	67.87	60.57	54.61	36.31
1000 ppm	100	98.04	96.44	94.50	93.02	70.58	56.81	37.84	32.04
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.2: Weight of sodium benzoate treated mango (%) at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
10 ppm	100	97.56	87.88	82.54	71.04	69.12	39.54	29.38	0
20 ppm	100	97.04	88.45	86.23	79.31	59.40	45.05	35.07	0
30 ppm	100	97.66	88.02	83.77	79.27	76.52	46.63	33.89	0
40 ppm	100	97.87	95.33	93.04	77.80	61.53	39.47	16.75	0
50 ppm	100	97.05	94.80	90.82	86.45	54.30	32.12	17.68	0
60 ppm	100	97.27	87.43	84.53	73.58	58.34	33.37	12.44	0
70 ppm	100	97.36	94.71	92.67	90.89	82.32	53.90	46.74	28.66
80 ppm	100	97.15	95.01	92.67	90.80	76.78	64.19	46.71	38.46
90 ppm	100	98.06	95.44	90.65	84.63	75.57	57.51	40.78	28.87
100 ppm	100	97.43	94.66	89.74	84.92	76.30	69.00	48.30	24.63
500 ppm	100	97.18	81.19	79.65	67.18	54.38	79.72	17.85	0
1000 ppm	100	97.43	94.98	89.423	88.05	72.03	59.28	46.85	0
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.3: Weight of acetic acid treated mango (%) at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
10 ppm	100	98.00	95.12	92.83	91.60	76.85	60.15	32.26	35.84
20 ppm	100	97.92	95.15	84.45	79.82	76.51	53.90	28.53	0
30 ppm	100	98.01	95.47	89.53	78.07	75.70	56.98	28.67	0
40 ppm	100	97.65	88.69	83.19	78.12	56.18	51.01	54.41	0
50 ppm	100	98.06	95.76	90.66	84.61	59.34	39.10	14.66	0
60 ppm	100	98.26	96.16	88.27	92.44	71.31	52.74	15.94	0
70 ppm	100	97.07	95.54	89.85	88.79	70.52	50.32	9.82	0
80 ppm	100	97.27	65.80	91.09	71.35	53.11	38.10	11.76	0
90 ppm	100	97.55	95.46	93.90	76.54	58.14	38.43	16.41	0
100 ppm	100	97.44	95.04	89.92	91.872	82.56	76.8	51.84	43.97
500 ppm	100	99.37	97.58	92.81	82.68	48.39	42.93	24.08	0
1000 ppm	100	96.80	94.54	92.61	91.30	76.13	63.18	24.56	0
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.4: Weight of glycerine treated mango (%) at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
1 drop once	100	96.23	95.29	93.58	91.77	83.04	46.03	17.29	0
1 drop everyday	100	95.95	94.83	93.16	91.06	64.66	34.00	0	0
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.5: Weight of water wash treated mango (%) at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
Water 1	100	97.66	95.43	93.93	92.51	84.31	78.24	24.50	0
Water 2	100	97.63	88.86	87.10	74.64	59.55	53.40	16.50	0
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.6: Comparative weight (%) of control mango and mango of best treatment at day by day during storage period cultivar of Himsagar

Treatments Designated mango	Weight of mango (%)								
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
Tetracycline 500 ppm	100	98.704	96.31	91.16	78.61	67.87	60.57	54.61	36.31
Sodium benzoate 80 ppm	100	97.15	95.01	92.67	90.80	76.78	64.19	46.71	38.46
Acetic acid 100 ppm	100	97.44	95.04	89.92	91.872	82.56	76.8	51.84	43.97
Glycerine 1 drop once	100	96.23	95.29	93.58	91.77	83.04	46.03	17.29	0
Water wash	100	97.66	95.43	93.93	92.51	84.31	78.24	24.50	0
Control	100	98.99	88.90	77.68	60.93	40.98	35.29	23.09	0

Table 4.7: Weight of tetracycline treated mango (%) at day by day during storage period cultivar of Langra

Treatments Designated mango	Weight of mango (%)												
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
10 ppm	100	97.28	95.15	92.94	89.951	82.59	80.96	68.45	44.97	50.91	44.70	38.42	21.73
20 ppm	100	97.29	94.67	92.24	82.25	81.09	69.26	45.13	29.07	15.66	0	0	0
30 ppm	100	96.73	94.76	95.05	89.32	88.00	68.87	56.56	43.21	26.55	14.23	0	0
40 ppm	100	97.06	95.32	93.01	90.07	88.76	87.31	62.69	39.99	17.29	17.02	0	0
50 ppm	100	97.60	95.42	93.14	90.47	89.02	87.31	64.04	50.86	34.62	22.91	16.37	5.86
60 ppm	100	97.47	95.33	92.67	85.63	84.49	76.23	39.91	21.84	15.84	15.73	0	0
70 ppm	100	97.49	95.21	92.91	90.26	88.66	82.66	57.17	34.47	15.96	10.61	0	0
80 ppm	100	97.63	95.39	93.20	90.50	89.07	77.02	69.69	41.27	29.23	21.49	5.14	0
90 ppm	100	97.34	95.18	92.89	89.99	82.46	81.03	70.15	56.77	46.15	22.60	22.08	6.03
100 ppm	100	97.15	94.79	87.56	84.82	83.35	82.15	59.00	31.29	25.71	25.12	24.71	6.62
200 ppm	100	97.19	95.07	66.30	90.05	88.29	86.56	75.22	52.57	28.61	11.99	0	0
300 ppm	100	97.41	94.94	92.74	83.93	82.51	80.87	52.28	28.84	18.27	0	0	0
400 ppm	100	97.45	94.72	92.50	90.08	88.31	86.80	74.05	56.89	27.62	0	0	0
500 ppm	100	96.70	94.19	91.63	88.99	69.37	57.65	23.72	23.06	16.70	0	0	0
1000 ppm	100	97.10	94.84	92.90	89.91	75.90	74.56	62.10	27.57	16.46	0	0	0
Control	100	97.92	95.73	93.93	91.30	85.18	83.13	76.80	50.91	32.33	0	0	0

Table 4.8: Weight of sodium benzoate treated mango (%) at day by day during storage period cultivar of Langra

Treatments Designated mango	Weight of mango (%)												
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
10 ppm	100	96.67	94.90	91.98	89.72	88.30	81.37	79.96	42.19	21.73	0	0	0
20 ppm	100	97.01	94.95	92.49	89.66	82.87	81.06	75.60	58.47	32.24	18.69	0	0
30 ppm	100	95.24	93.45	91.00	88.47	79.63	78.05	76.86	48.52	30.54	20.45	0	0
40 ppm	100	97.14	95.17	92.58	89.96	88.35	81.31	69.37	39.99	17.05	21.14	0	0
50 ppm	100	95.89	94.01	91.42	88.89	87.32	79.44	73.37	54.98	42.35	16.25	0	0
60 ppm	100	96.30	94.55	92.04	89.59	88.42	79.60	78.69	33.01	20.65	13.76	0	0
70 ppm	100	96.00	94.16	91.41	89.18	82.34	80.45	72.97	46.36	45.49	22.00	21.58	16.77
80 ppm	100	95.86	94.09	91.13	88.75	60.98	75.24	56.66	20.33	19.79	0	0	0
90 ppm	100	96.13	94.11	91.35	81.46	80.19	78.17	59.84	27.51	21.11	25.44	0	0
100 ppm	100	96.21	94.44	85.76	83.58	82.09	80.25	79.42	60.42	48.83	26.69	26.35	26.00
200 ppm	100	95.47	93.69	90.80	88.43	81.91	80.06	44.18	16.05	15.92	10.48	0	0
300 ppm	100	95.84	93.94	91.53	89.12	87.40	73.68	50.23	32.56	32.15	15.95	0	0
400 ppm	100	95.88	93.97	91.05	89.12	81.26	68.44	39.34	28.37	22.47	16.26	0	0
500 ppm	100	95.91	94.20	91.21	89.04	87.44	85.54	67.95	49.10	31.46	14.92	0	0
1000 ppm	100	95.91	94.17	91.38	88.96	87.40	85.58	61.55	45.17	17.44	12.71	0	0
Control	100	97.92	95.73	93.93	91.30	85.18	83.13	76.80	50.91	32.33	0	0	0

Table 4.9: Weight of acetic acid treated mango (%) at day by day during storage period cultivar of Langra

Treatments Designated mango	Weight of mango (%)												
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
10 ppm	100	97.07	95.07	86.72	84.52	83.09	81.07	80.06	57.57	35.50	16.52	0	0
20 ppm	100	97.15	95.03	91.93	84.37	77.31	70.20	58.73	45.85	28.91	10.66	0	0
30 ppm	100	97.23	95.06	92.34	90.03	88.33	81.71	67.98	49.77	26.78	15.93	0	0
40 ppm	100	97.33	95.27	92.40	89.76	88.58	81.67	55.19	44.61	15.35	10.04	0	0
50 ppm	100	97.46	95.48	87.34	84.82	84.01	77.00	58.74	44.56	21.16	11.04	0	0
60 ppm	100	97.25	94.91	92.40	89.65	75.59	74.56	57.18	44.87	22.20	11.33	0	0
70 ppm	100	97.09	95.44	92.78	90.25	88.98	77.25	70.08	51.83	38.94	20.93	20.47	9.07
80 ppm	100	97.16	94.70	92.35	89.38	88.12	64.85	48.48	41.71	30.15	17.58	0	0
90 ppm	100	97.39	95.18	92.55	89.58	77.05	69.82	56.57	37.41	20.15	9.83	0	0
100 ppm	100	97.32	95.17	87.95	85.29	83.87	82.68	74.84	56.23	27.41	20.83	20.31	14.97
200 ppm	100	97.57	95.38	92.51	89.46	88.13	80.62	63.15	49.45	18.38	0	0	0
300 ppm	100	97.74	95.85	93.21	85.41	83.88	70.49	57.64	45.83	23.30	17.24	0	0
400 ppm	100	97.59	95.49	93.19	90.21	88.87	74.89	56.95	38.48	15.56	0	0	0
500 ppm	100	97.45	95.52	87.02	84.45	83.45	75.54	51.04	44.76	15.20	0	0	0
1000 ppm	100	97.04	94.86	86.23	83.41	82.22	81.09	51.13	45.29	28.59	15.90	0	0
Control	100	97.92	95.73	93.93	91.30	85.18	83.13	76.80	50.91	32.33	0	0	0

Table 4.10: Weight of water wash treated mango (%) at day by day during storage period cultivar of Langra

Treatments Designated mango	Weight of mango (%)												
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
Water	100	97.39	95.13	92.68	84.03	82.22	75.24	44.62	29.29	18.85	0	0	0
Control	100	97.92	95.73	93.93	91.30	85.18	83.13	76.80	50.91	32.33	0	0	0

Table 4.11: Comparative weight (%) of control mango and mango of best treatment at day by day during storage period cultivar of Langra

Treatments Designated mango	Weight of mango (%)												
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
Tetracycline 10 ppm	100	97.28	95.15	92.94	89.951	82.59	80.96	68.45	44.97	50.91	44.70	38.42	21.73
Sodium benzoate 100 ppm	100	96.21	94.44	85.76	83.58	82.09	80.25	79.42	60.42	48.83	26.69	26.35	26.00
Acetic acid 100 ppm	100	97.32	95.17	87.95	85.29	83.87	82.68	74.84	56.23	27.41	20.83	20.31	14.97
Control	100	97.92	95.73	93.93	91.30	85.18	83.13	76.80	50.91	32.33	0	0	0

4.2 Effects of preservatives on general quality

General physical qualities of control and preservative treated mango were compared by the judges on the basis of appearance, colour, flavor, taste and texture. It can be concluded from their suggestions that the preservatives treated mangoes are quite superior to that of control one (Table 4.12).

Table 4.12: The grading of control and preservatives treated mango as judged by the panel of judges based on general qualities of mango.

Sample	Treatments	Marking	Order of rating
Appearance	Treated*	95	Excellent
	control**	75	Good
Colour	Treated	90	Excellent
	control	70	Fair
Flavour	Treated	88	Excellent
	control	72	Fair
Taste	Treated	92	Excellent
	control	80	Good
Texture	Treated	95	Excellent
	control	78	Good

*Treated: Dipped in solution of preservatives

**Control: The control were marked and designed and kept at room temperatur

4.3 Effect on physiological loss in weight

Physiological loss in weight of control and preservative treated mango were compared. It can be concluded from the shelf life study that the preservatives treated mangoes showed reduced weight loss to that of control one at different concentrations (Fig. 4.1-4.22).

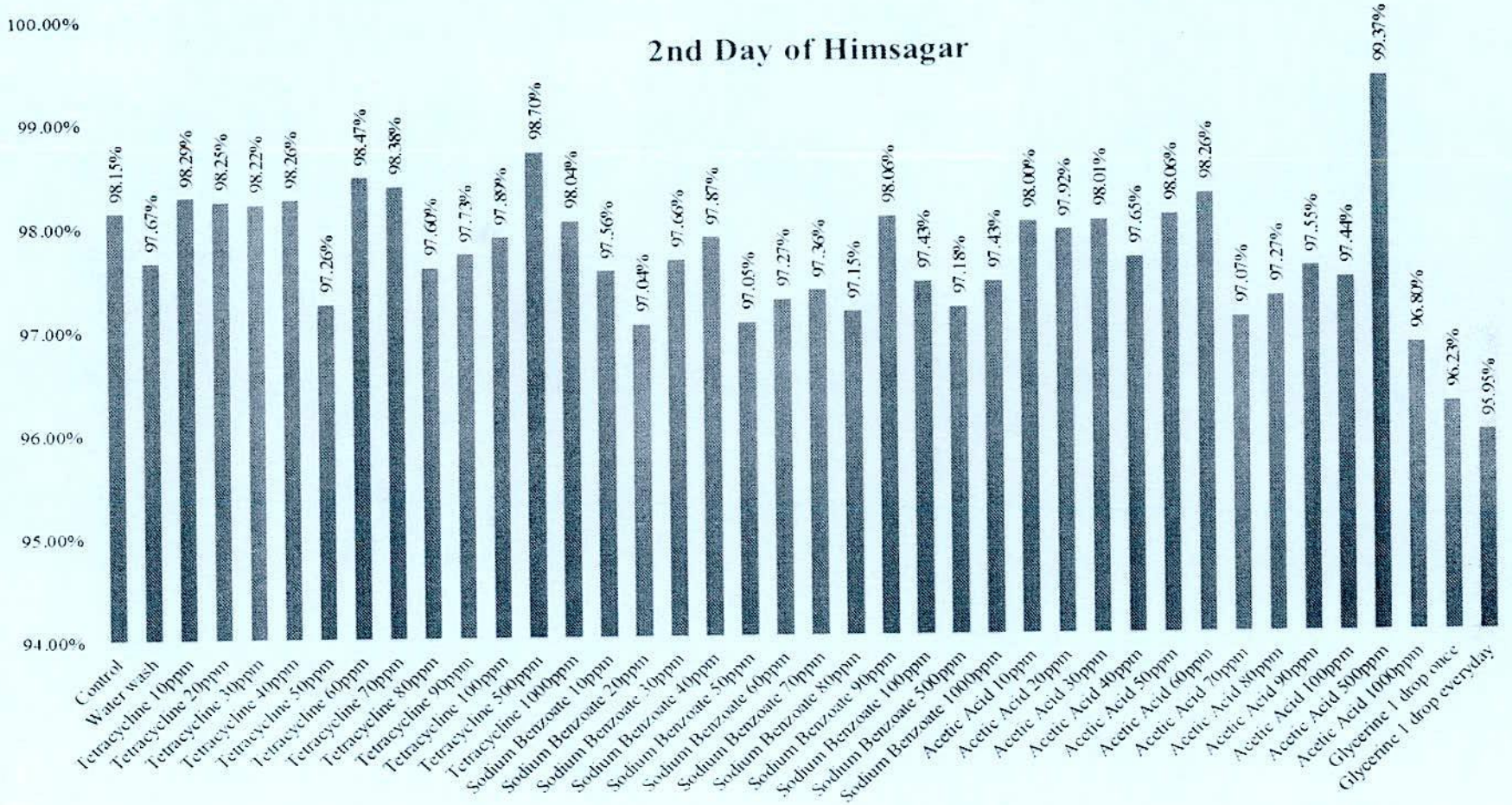


Figure 4.1: Weight of control and preservative treated Himsagar mango at 2nd day.

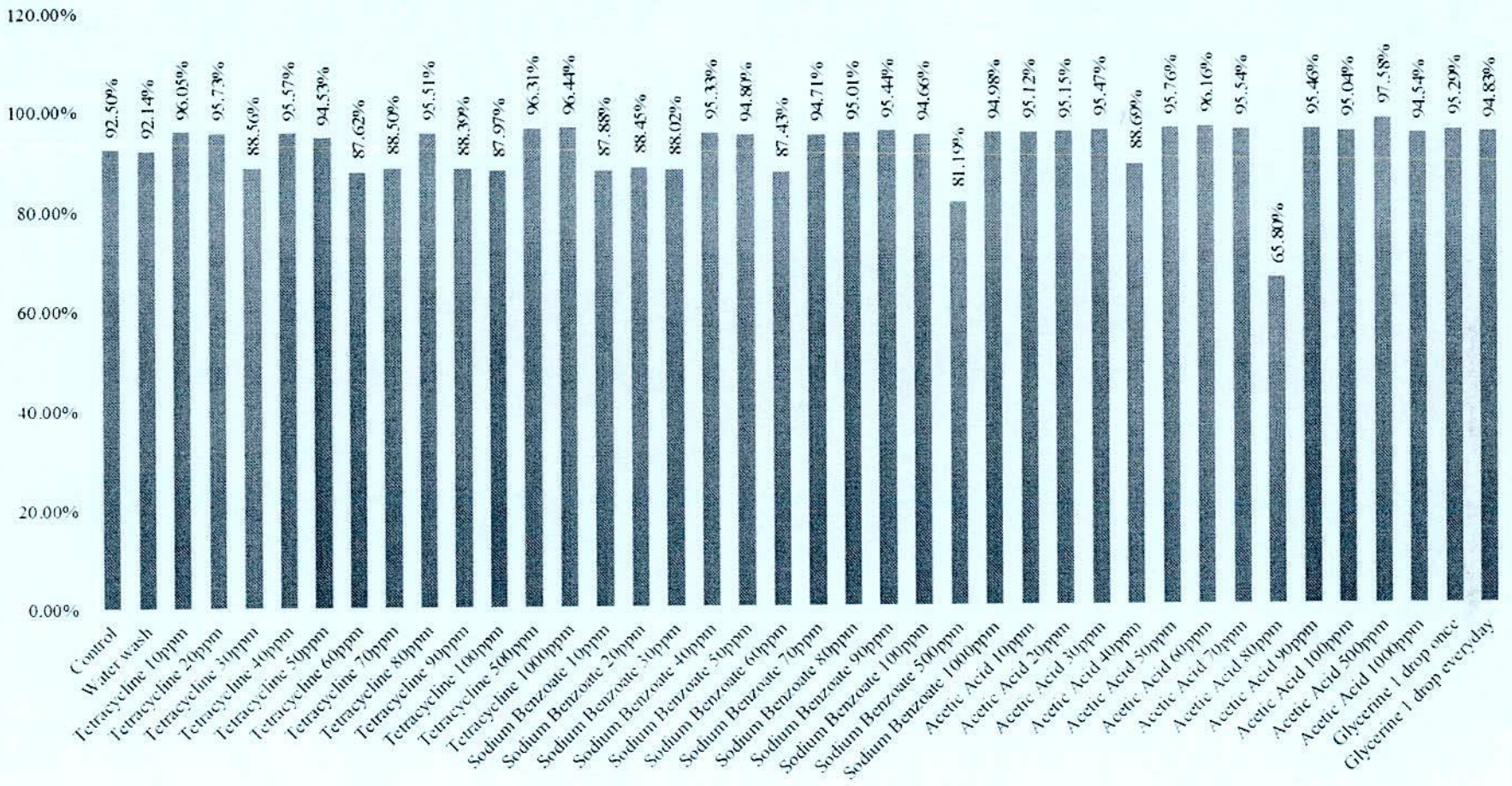


Figure 4.2: Weight of control and preservative treated Himsagar mango at 3rd day.

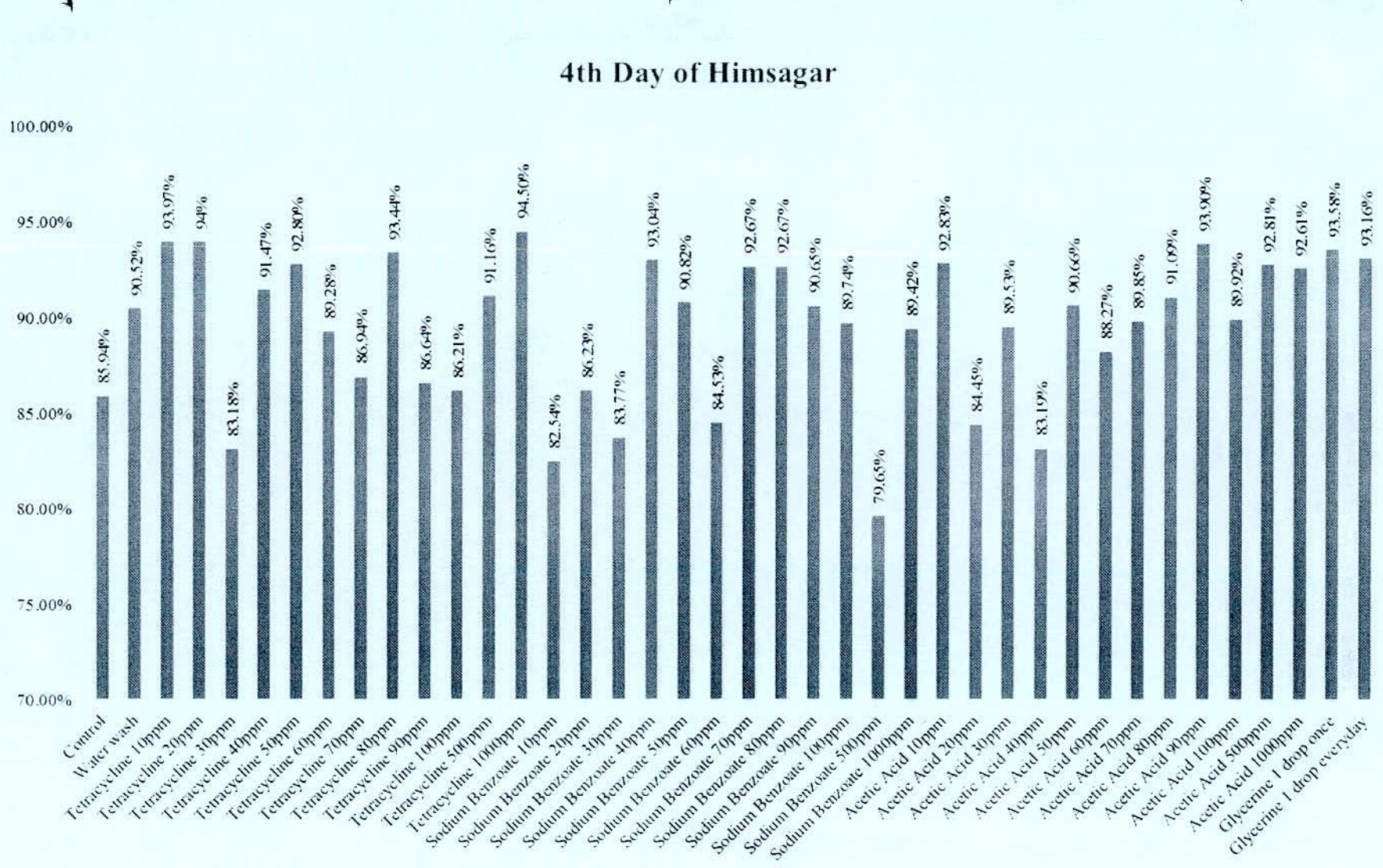


Figure 4.3: Weight of control and preservative treated Himsagar mango at 4th day.

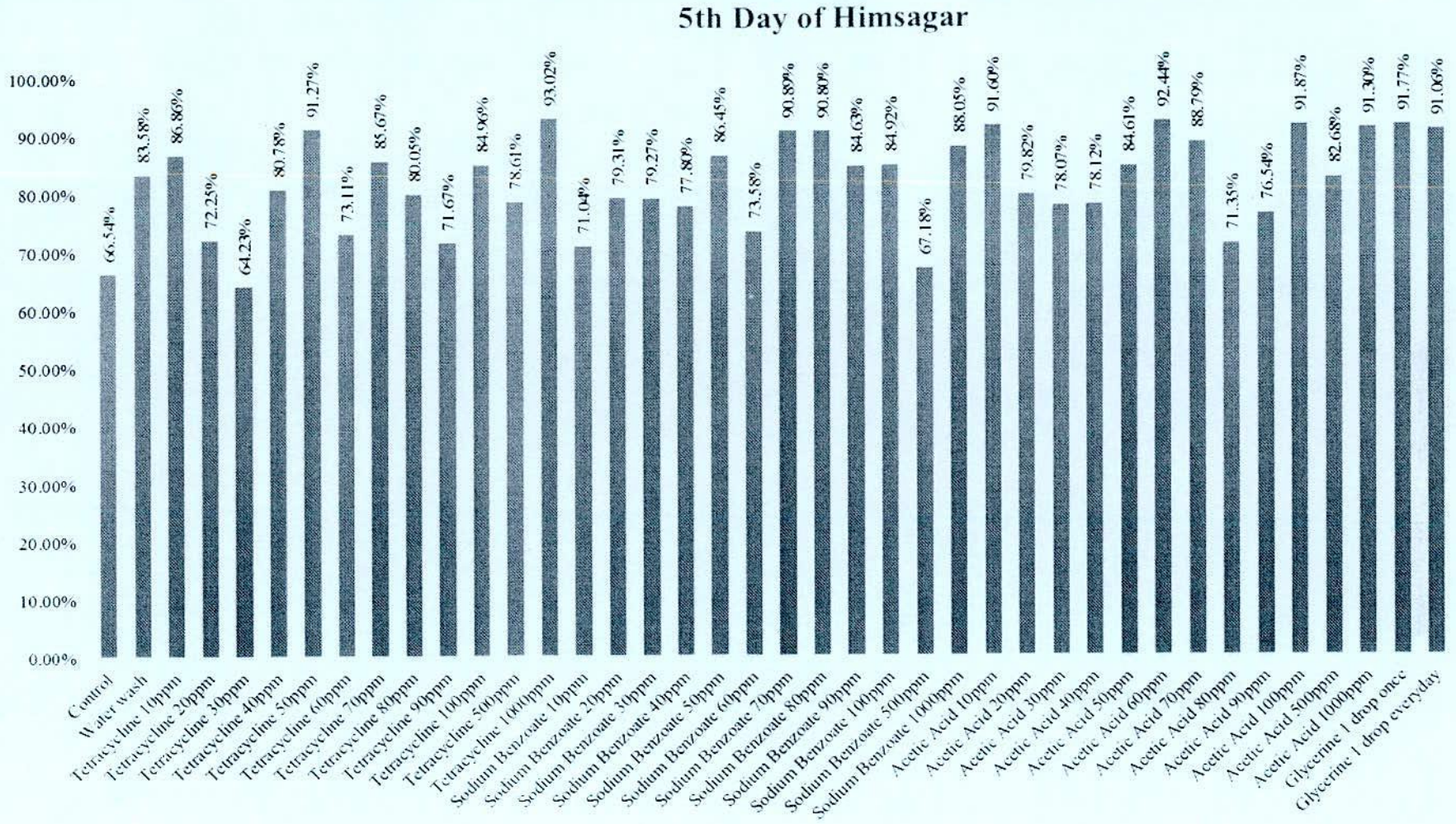


Figure 4.4: Weight of control and preservative treated Himsagar mango at 5th day.

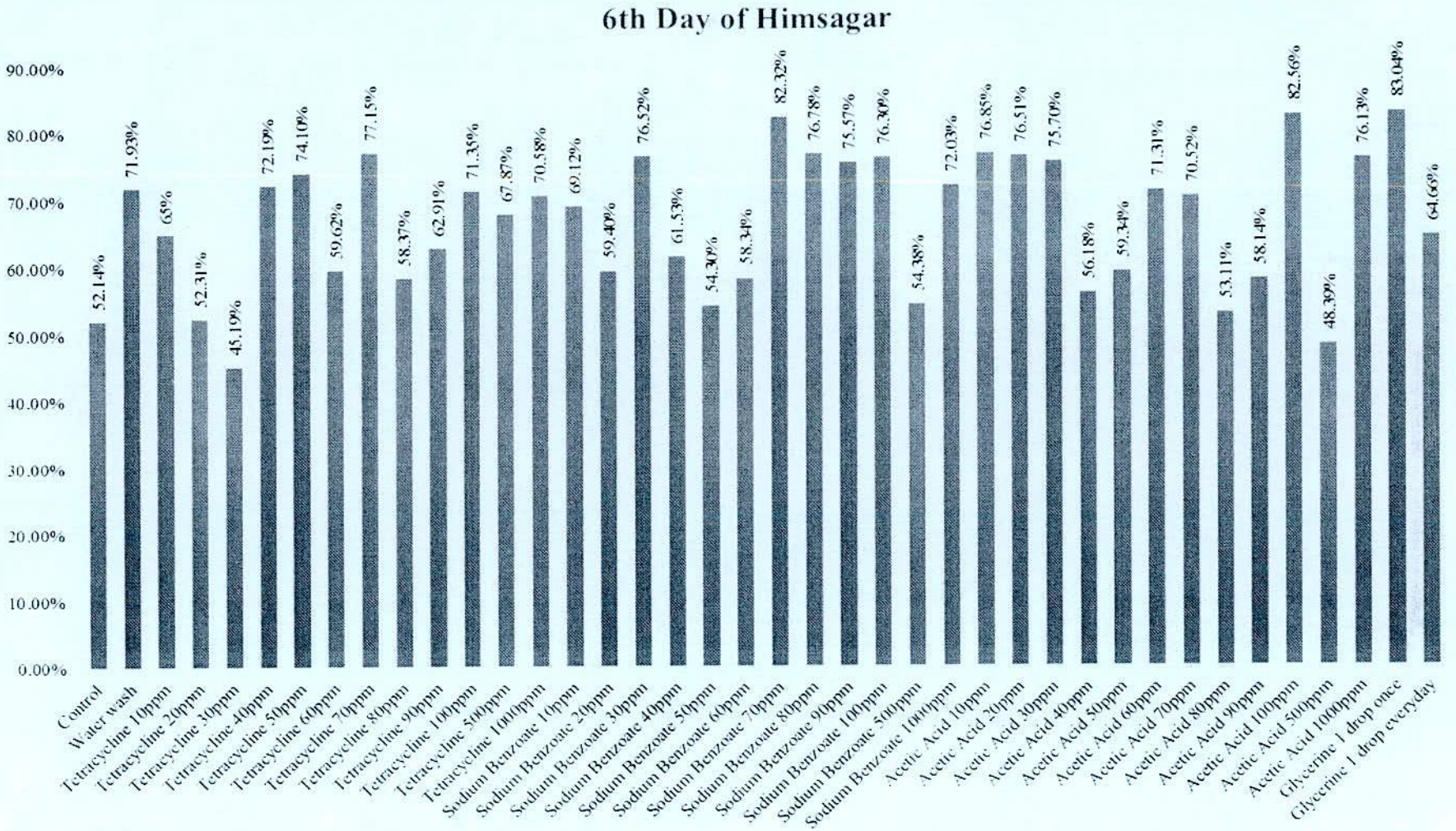


Figure 4.5: Weight of control and preservative treated Himsagar mango at 6th day.

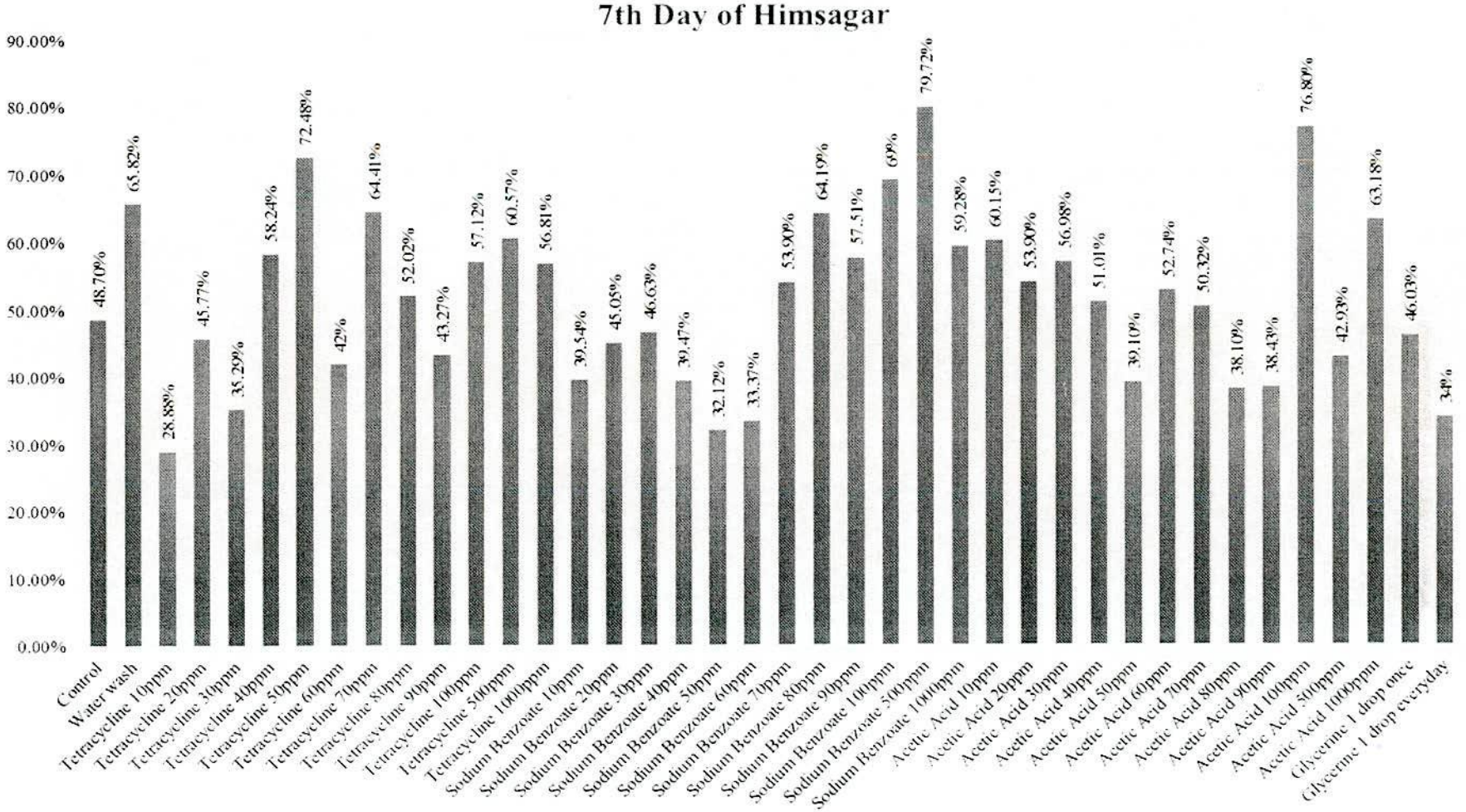


Figure 4.6: Weight of control and preservative treated Himsagar mango at 7th day.

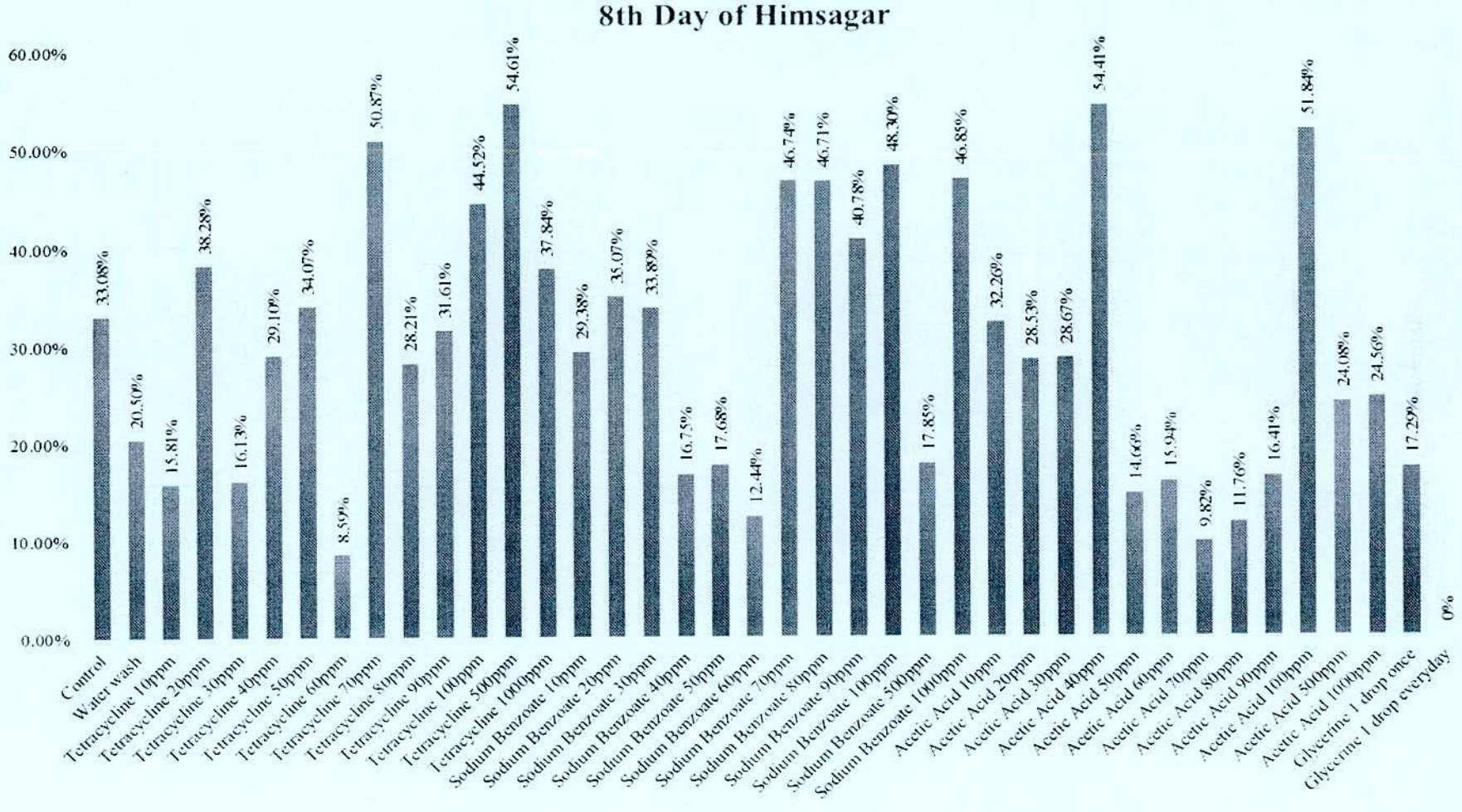


Figure 4.7: Weight of control and preservative treated Himsagar mango at 8th day.

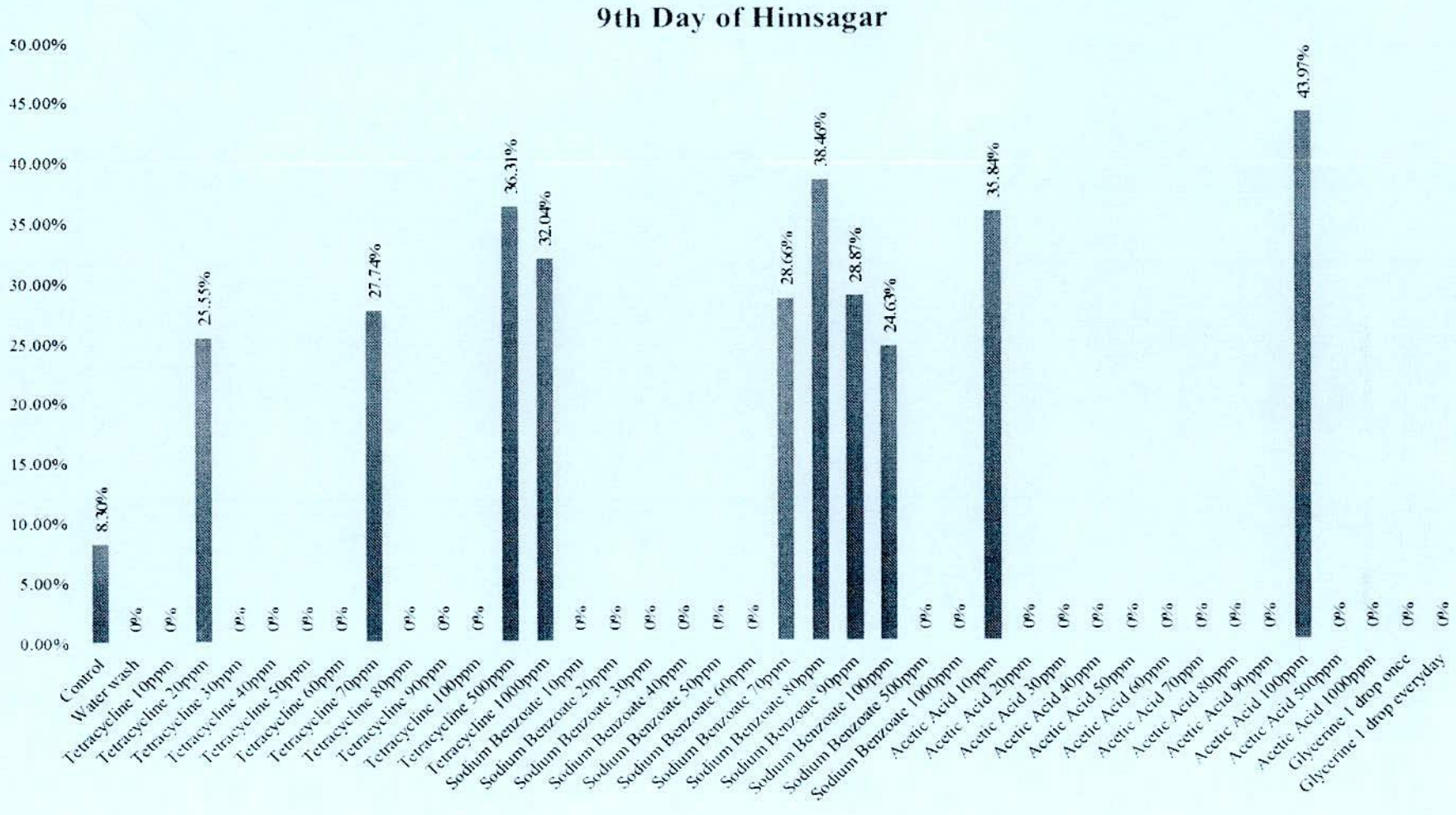


Figure 4.8: Weight of control and preservative treated Himsagar mango at 9th day.

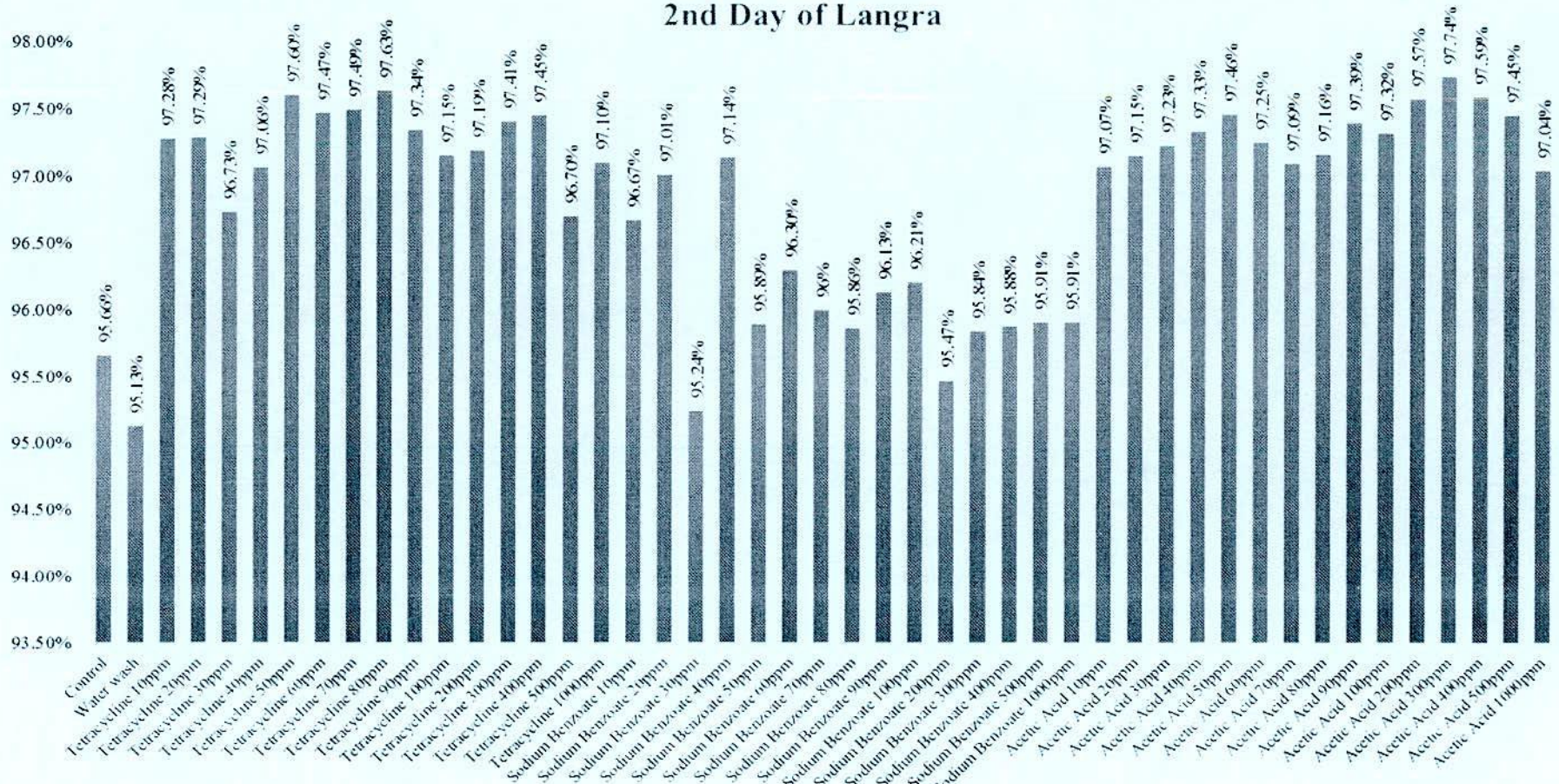


Figure 4.9: Weight of control and preservative treated Langra mango at 2nd day.

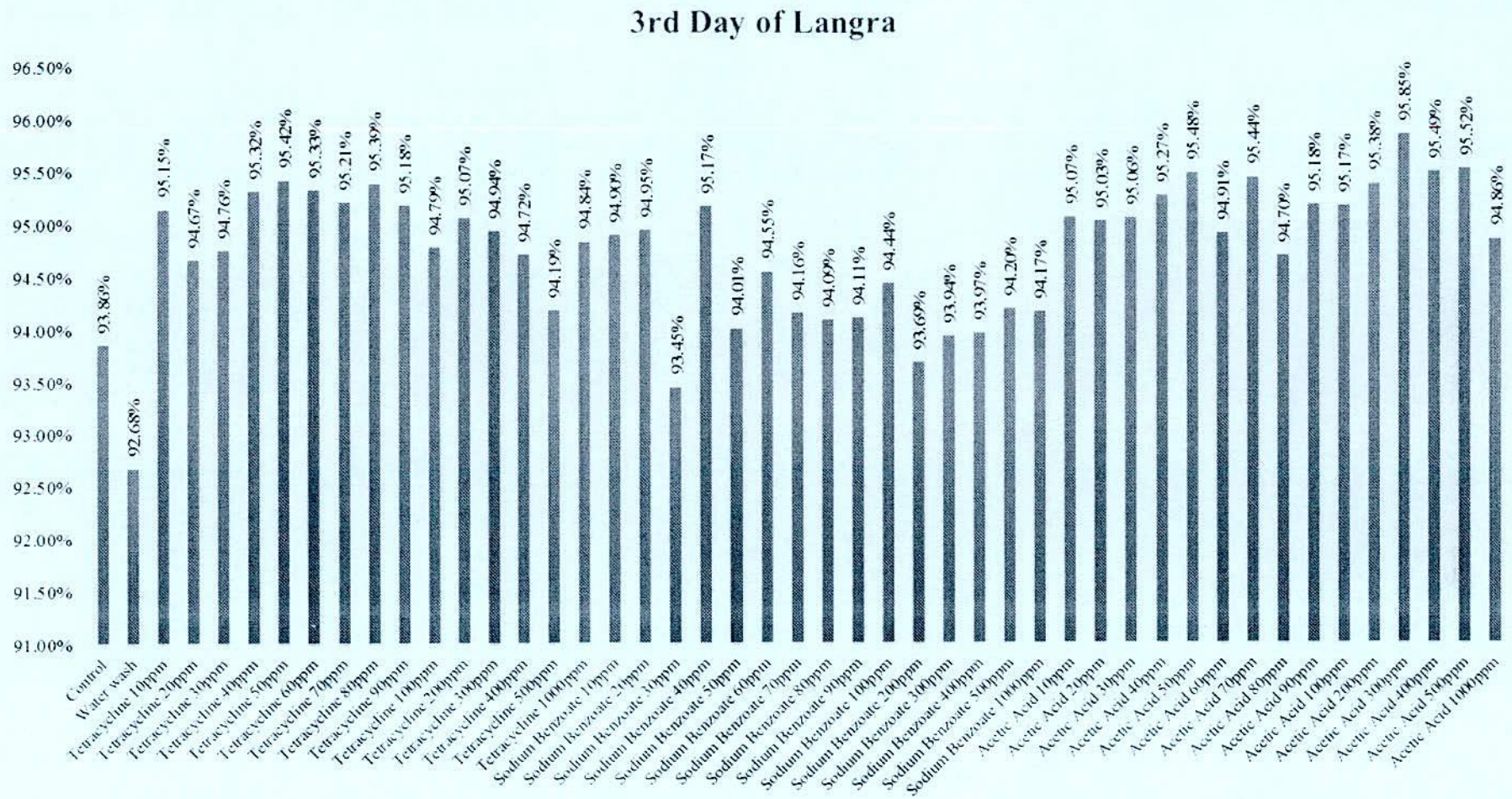


Figure 4.10: Weight of control and preservative treated Langra mango at 3rd day.

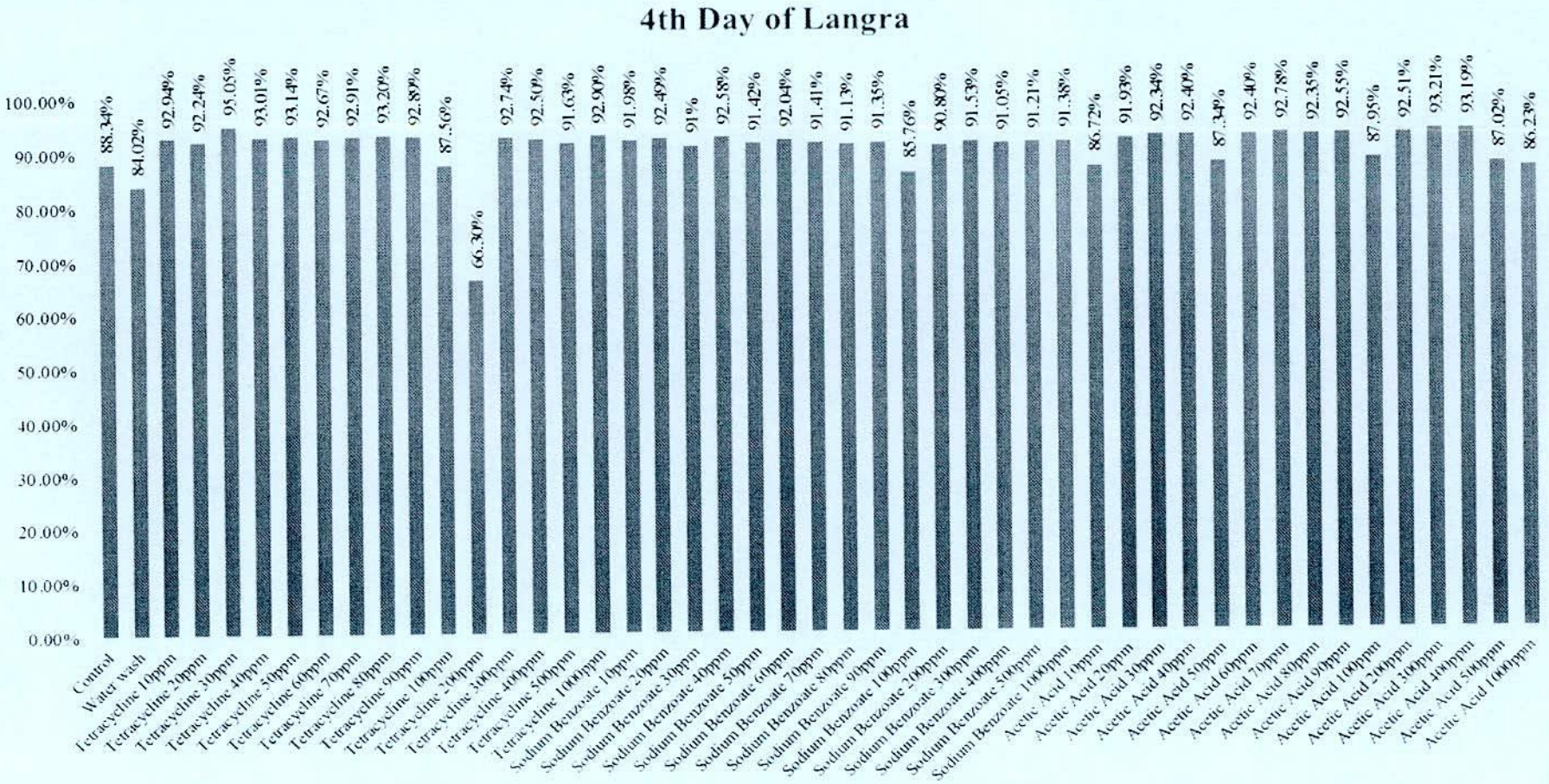


Figure 4.11: Weight of control and preservative treated Langra mango at 4th day.

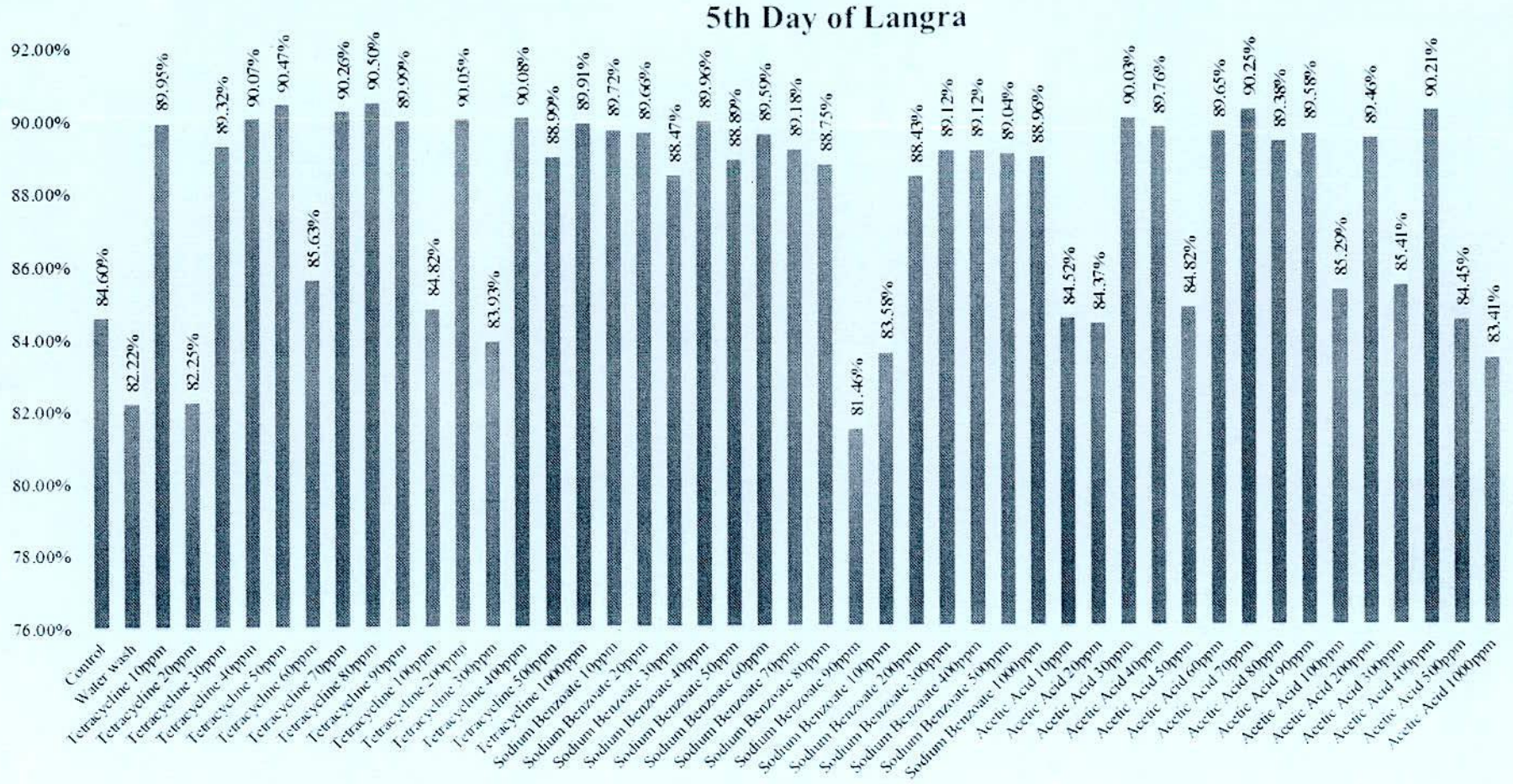


Figure 4.12: Weight of control and preservative treated Langra mango at 5th day.

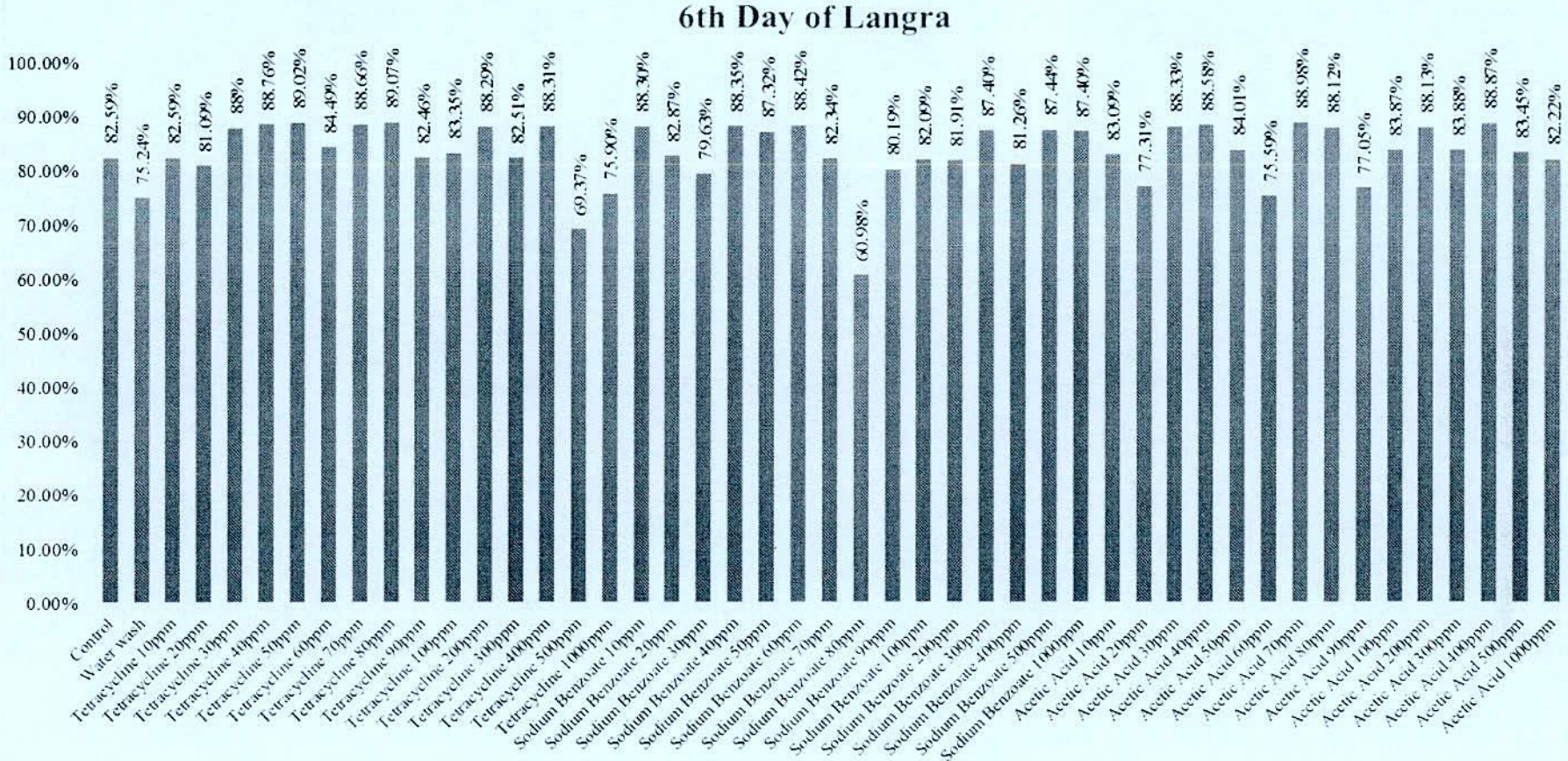


Figure 4.13: Weight of control and preservative treated Langra mango at 6th day.

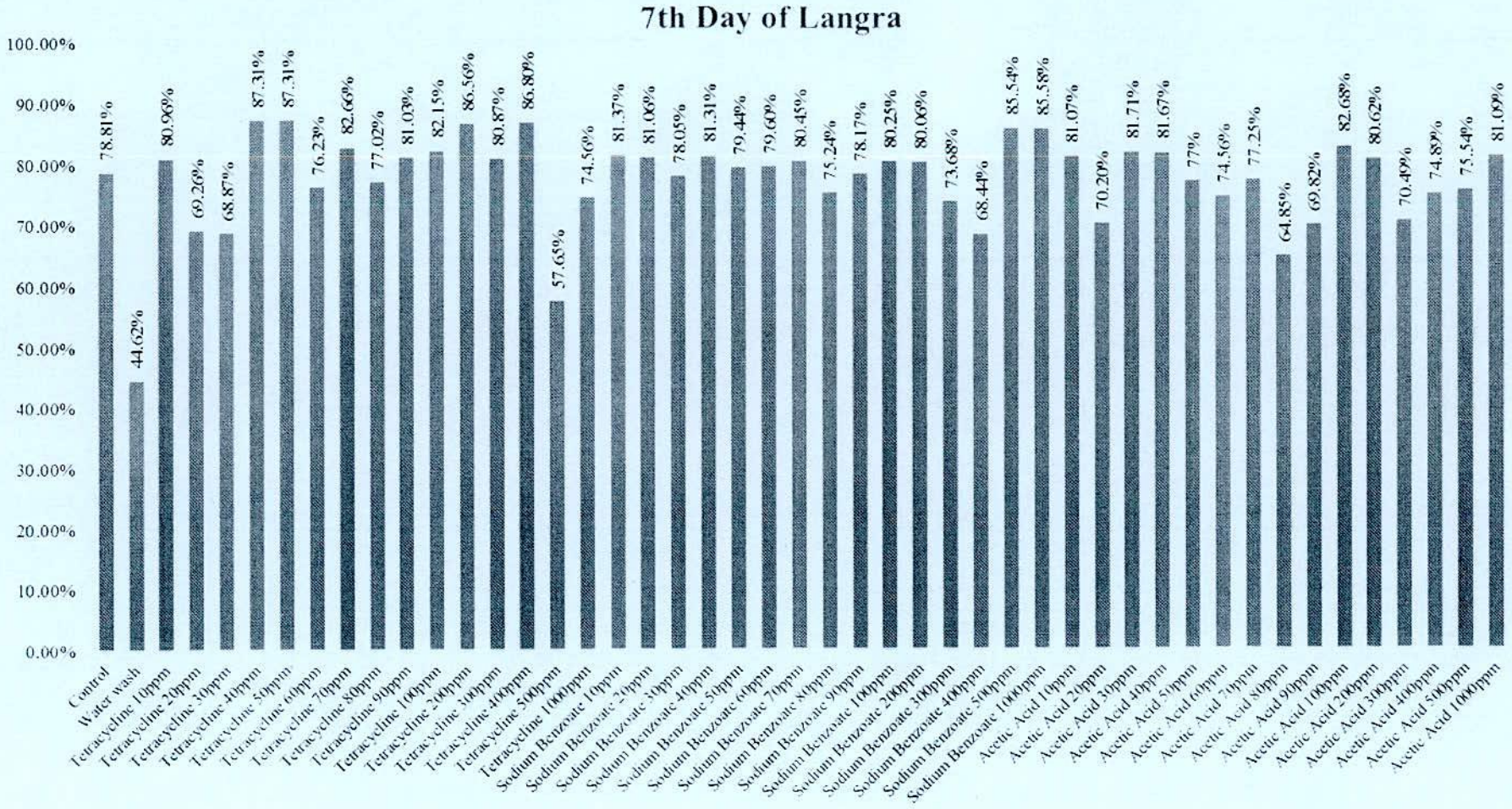


Figure 4.14: Weight of control and preservative treated Langra mango at 7th day.

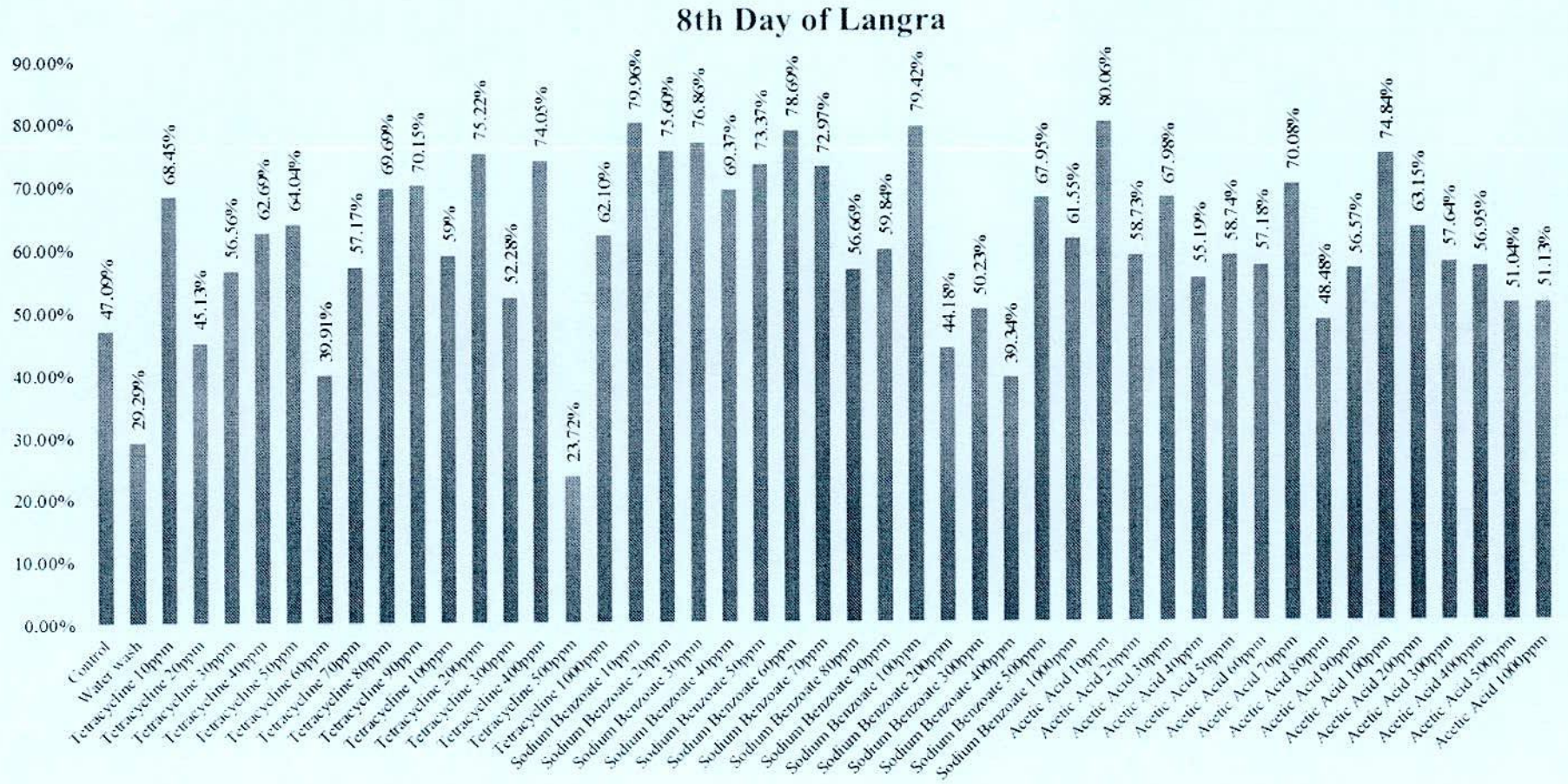


Figure 4.15: Weight of control and preservative treated Langra mango at 8th day.

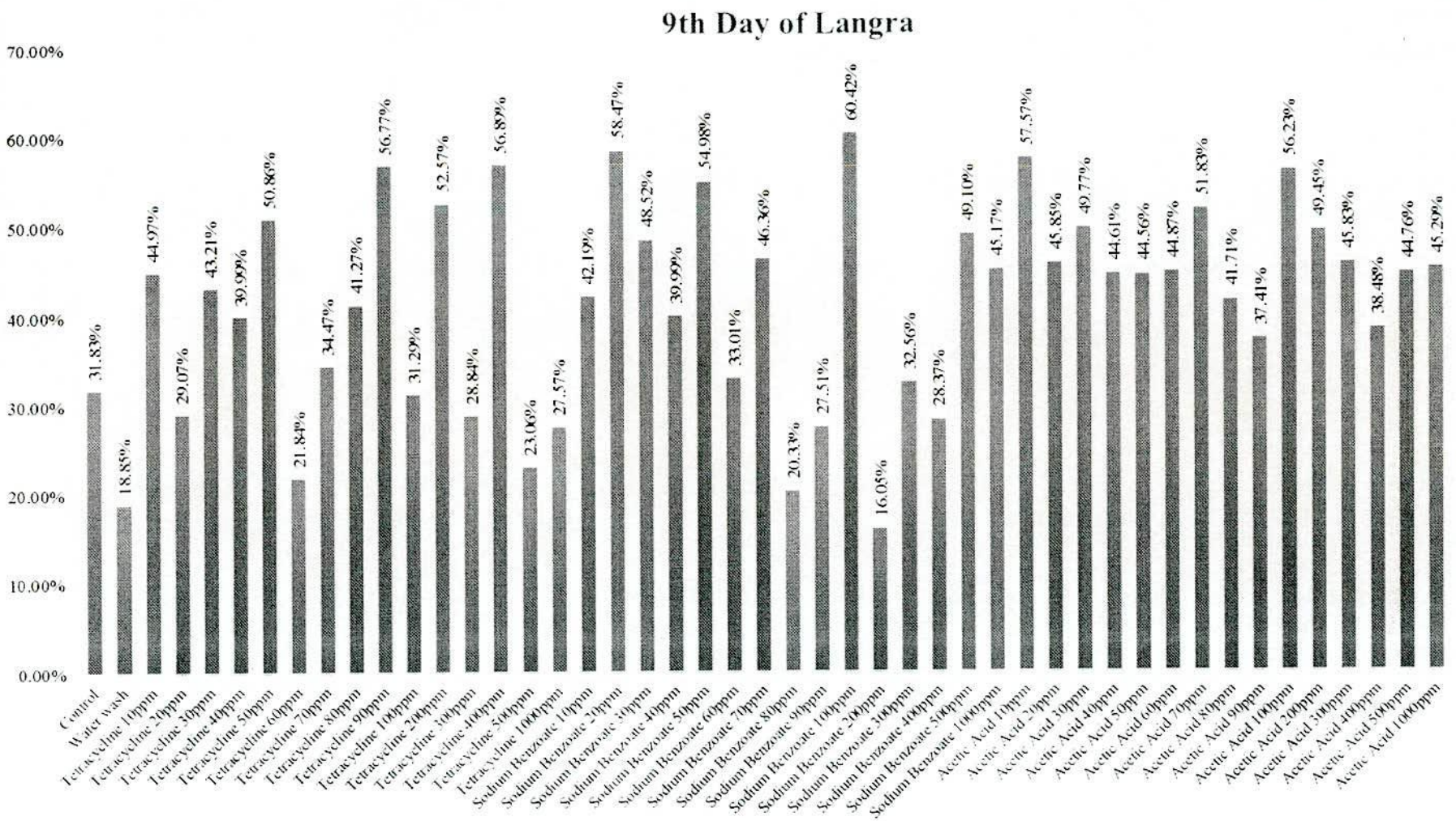


Figure 4.16: Weight of control and preservative treated Langra mango at 9th day.

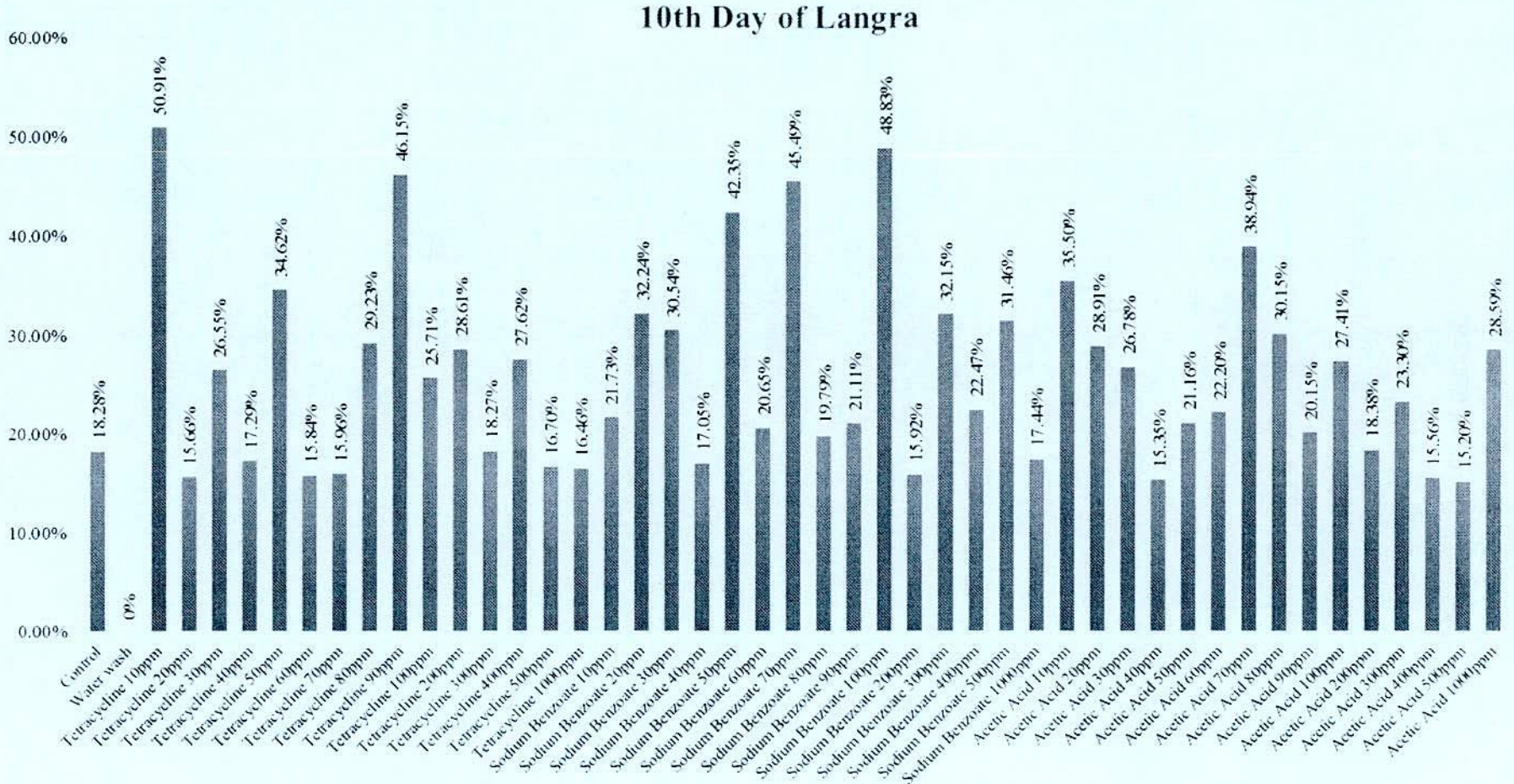


Figure 4.17: Weight of control and preservative treated Langra mango at 10th day.

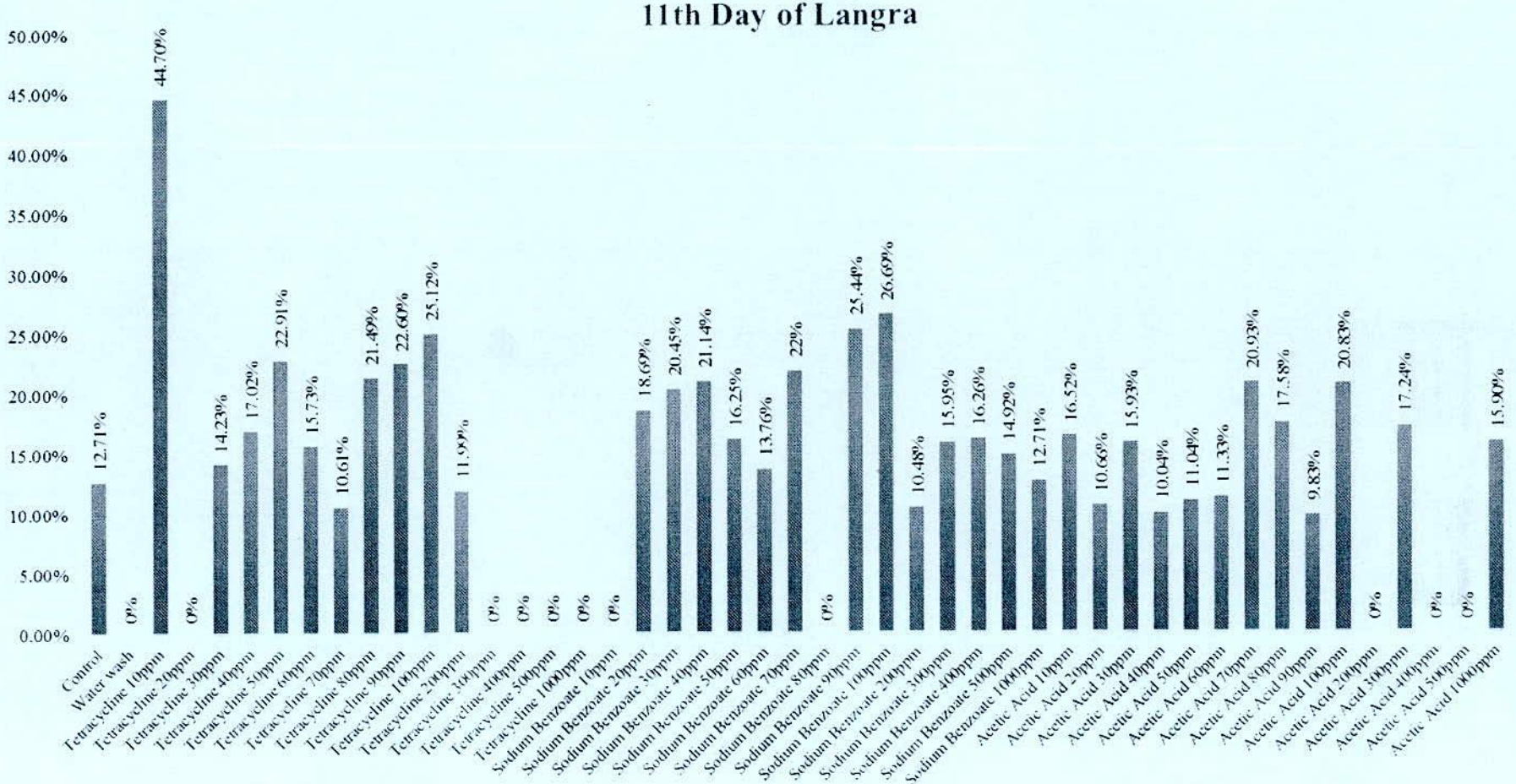


Figure 4.18: Weight of control and preservative treated Langra mango at 11th day.

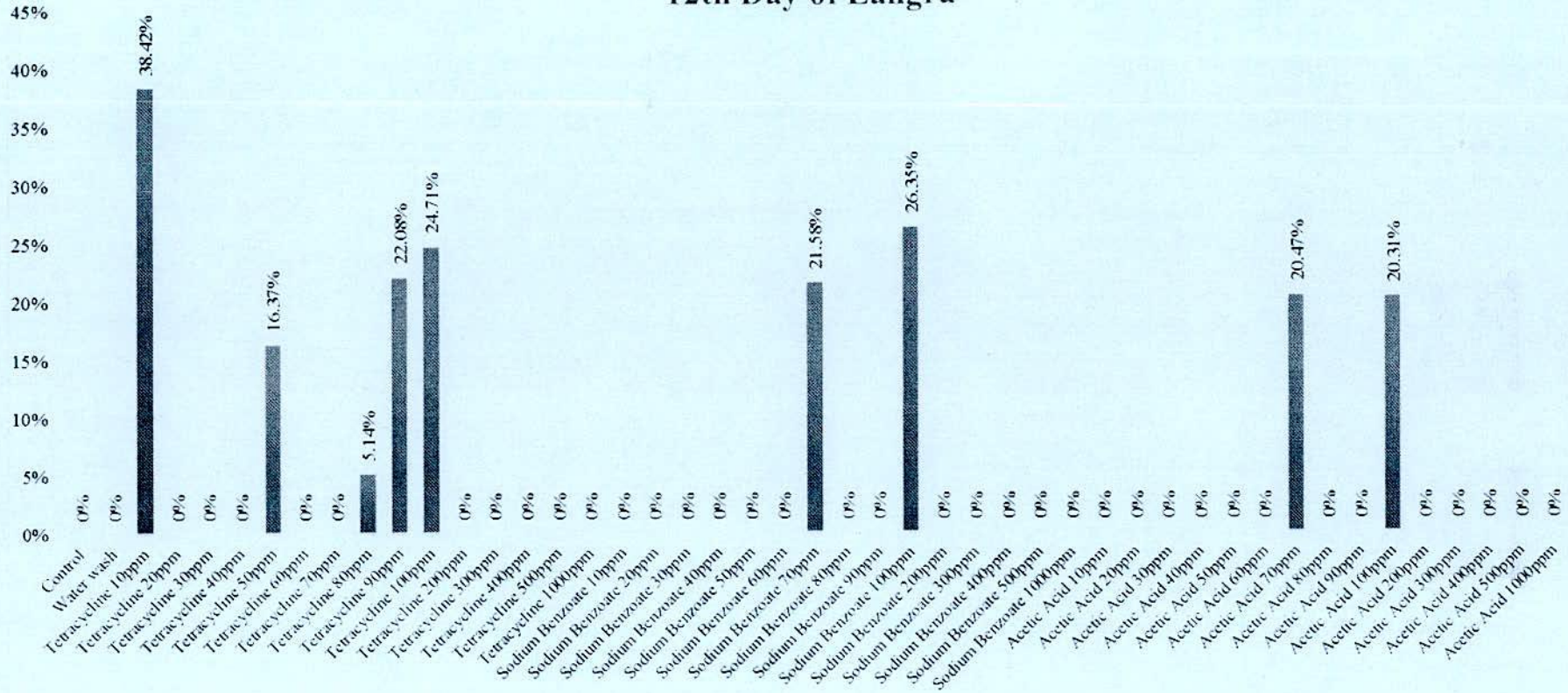


Figure 4.19: Weight of control and preservative treated Langra mango at 12th day.

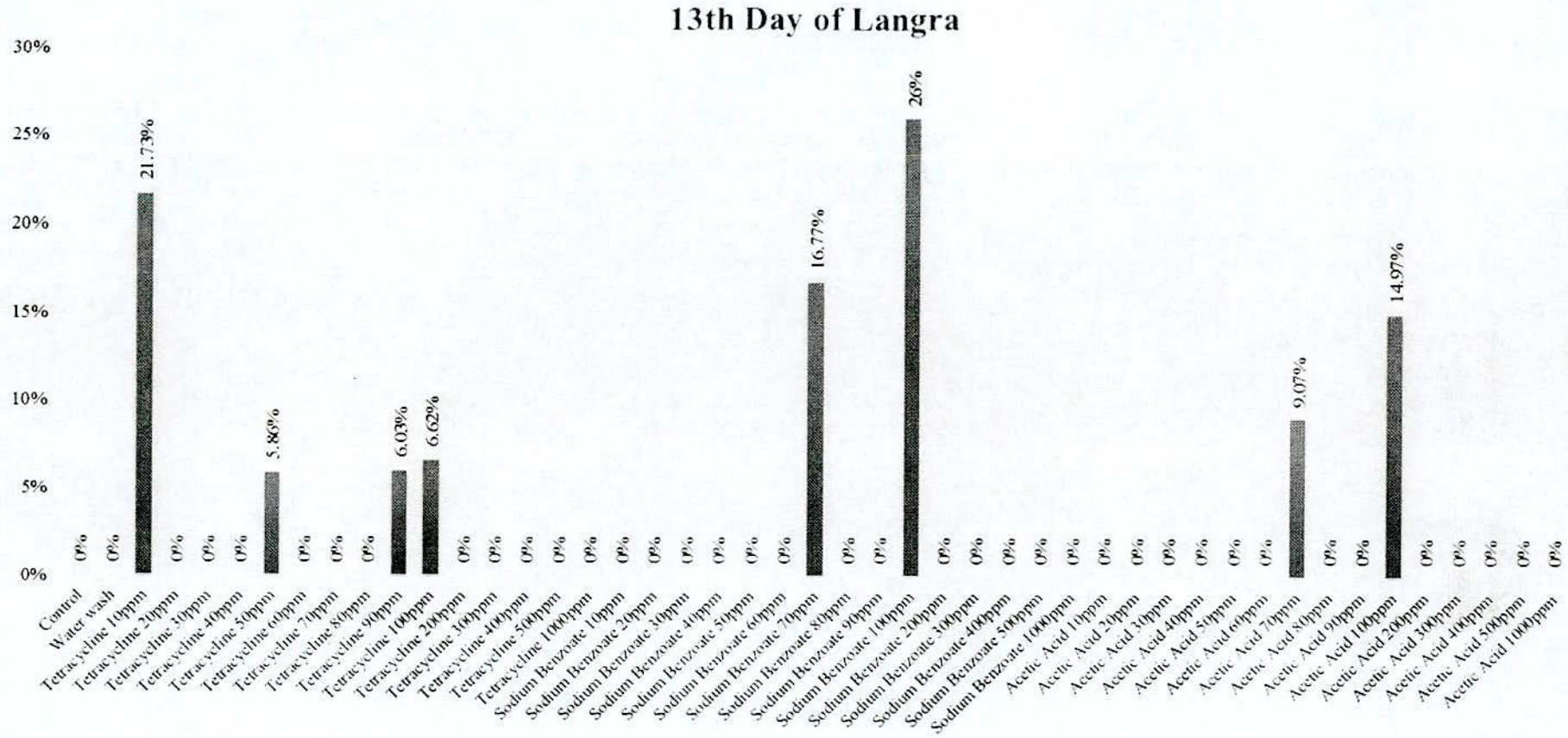


Figure 4.20: Weight of control and preservative treated Langra mango at 13th day.

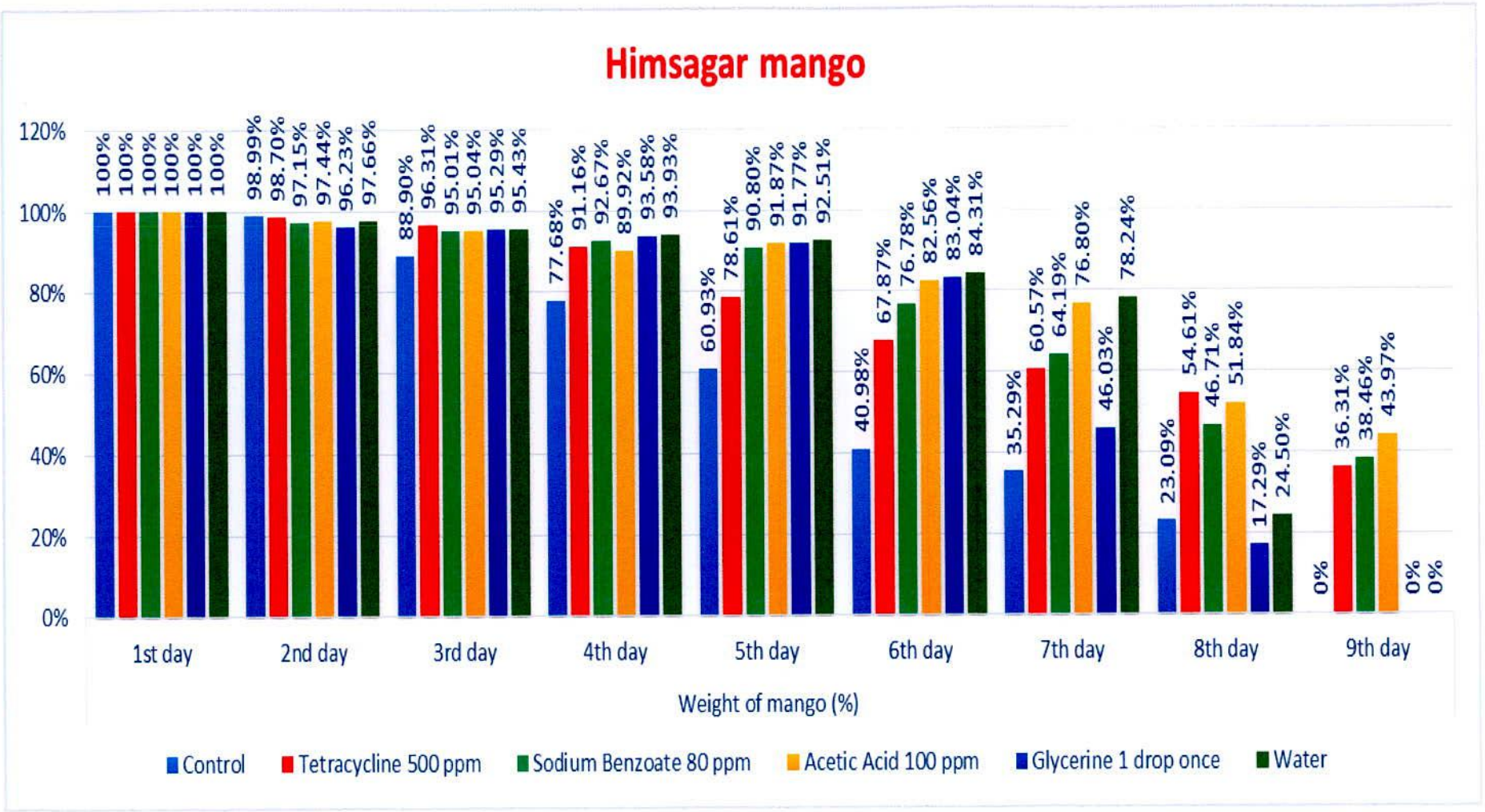


Figure 4.21: Comparative weight of control and preservatives treated Himsagar mango at 1st to 9th day.

4.4 Effects of preservatives on physical appearance

The physical appearance of preservative treated mango and control mango were compared. It was found from the physical appearance that the preservative treated mangoes showed more attractive appearance to that of control one at the same day (Fig 4.23-4.24).

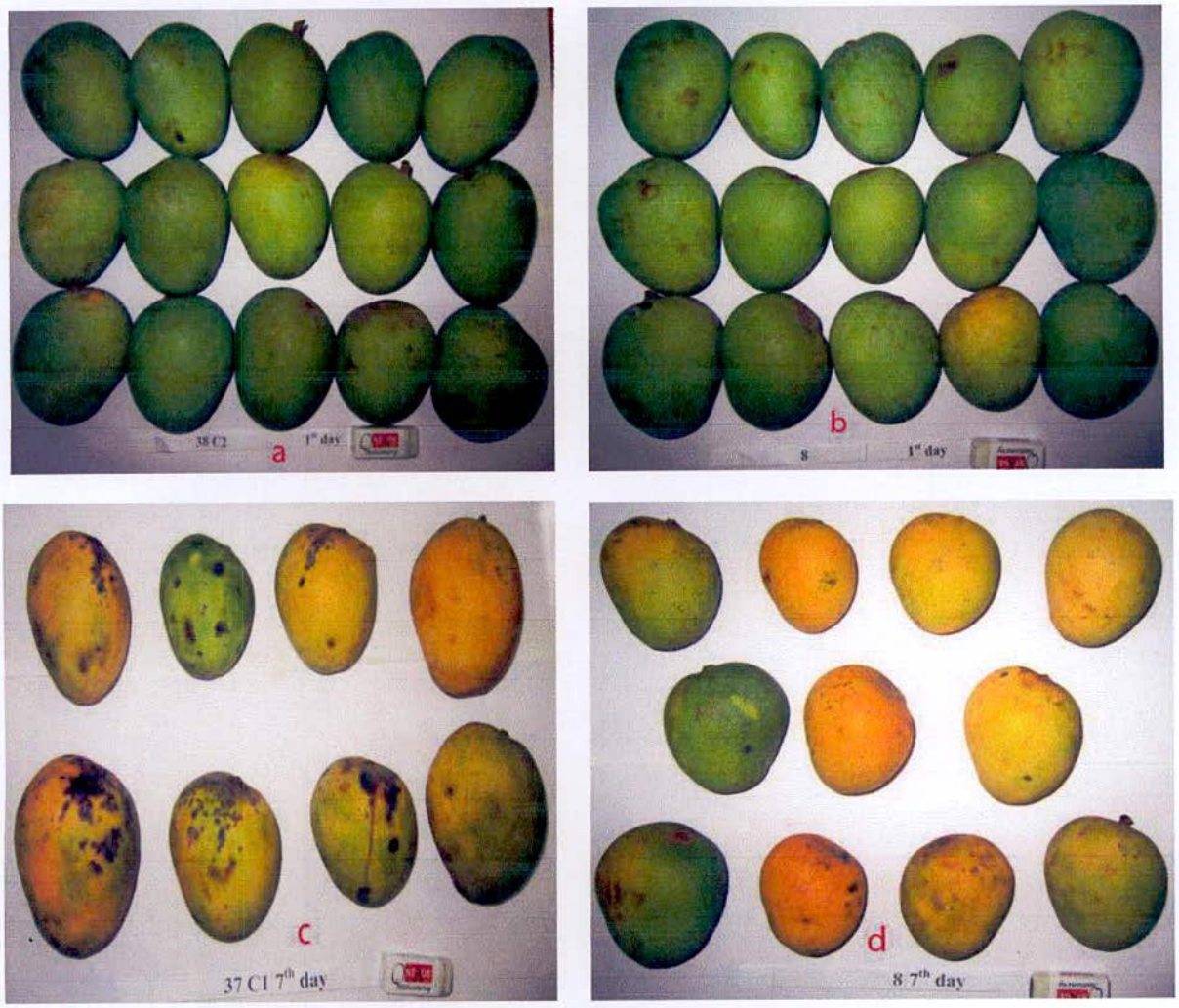


Figure 4.23: Control (a & c) and sodium benzoate 80 ppm (b & d) treated mango during storage period cultivar of Himsagar at (a) 1st day control (b) 1st day treatment (c) 7th day control (d) 7th day treatment.

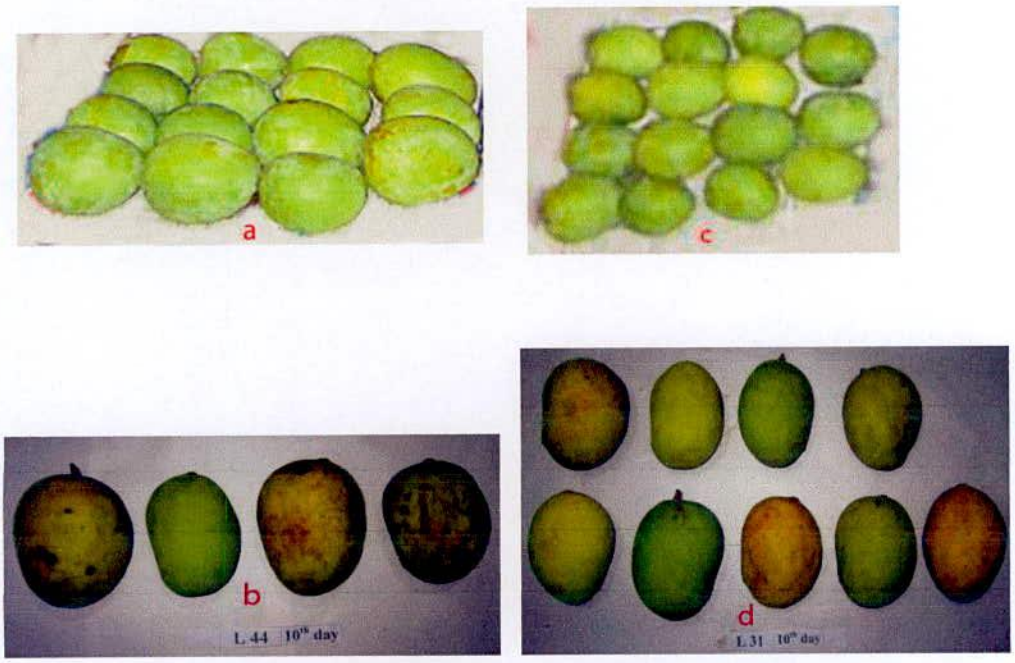


Figure 4.24: Control (a & b) and tetracycline 10 ppm (c & d) treated mango during storage period cultivar of Langra at (a) 1st day control (b) 10th day control (c) 1st day treatment (d) 10th day treatment.

4.5 Effects of preservatives on the improvement of quality

pH of mango pulp: As given in table 4.13 and 4.14 the pH in mango pulp was found to be higher in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp. But at the last edible stage the pH was found to be varied between 5.24 to 6.32 in preservatives treated mango pulp while that was found to be 5.19 in control mango pulp. The increase of pH was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94].

Total soluble solids (TSS) of mango pulp: It was found that the TSS was higher in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp (table 4.13 and 4.14). At the last edible stage the TSS content varied between 11.5% to 19% in preservatives treated mango pulp while that was found to be 10% in control mango pulp. The increase of TSS was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94]

Acidity of mango pulp: As given in table 4.13 and 4.14 the acidity in mango pulp was decreased the amount of acidity percentage as citric acid was found to be varied between 0.036 % to 0.07 % as citric acid in preservatives treated Himsagar and Langra mango pulp while that was found to be 0.08% as citric acid in control mango pulp. Reduction of acidities were also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94], in tomato fruits by Parthasarathy [95].

Ascorbic acid (vitamin C) content of mango pulp: As presented in table 4.13 and 4.14 like acidity, the ascorbic acid content of mango pulp was found to be higher in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp. At the last edible stage the ascorbic acid was found to be varied between 58.75 mg/100g to 94 mg/100g in preservatives treated mango pulp while that was found to be 47.6 mg/100g in control mango pulp. The increase of ascorbic acid was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94], in goose berry fruits by Gupta VK and Mukherjee D [96].

Protein content of mango pulp: As presented in table 4.13 and 4.14 like acidity, the protein content of mango pulp was found to be higher in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp. At the last edible stage the protein was found to be varied between 0.6%to 1.03% in preservatives treated mango pulp while that was found to be 0.57% in control mango pulp.

Total sugar content of mango pulp: As presented in table 4.13 and 4.14 like pH & TSS, the total sugar content of mango pulp was found to be higher in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp. At the last edible stage the total sugar was found to be varied between 11.53% to 12.39% in preservatives treated mango pulp while that was found to be 10.9% in control mango pulp. The increase of total sugar was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94] in goose berry fruits by Gupta VK and Mukherjee D [96].

Reducing sugar content of mango pulp: As given in table 4.13 and 4.14 like pH & TSS, the reducing sugar content of mango pulp was also increased in preservatives treated Himsagar and Langra mango pulp. At the last edible stage the reducing sugar was found to be varied between 4.73% to 5.46% in preservatives treated mango pulp while that was found to be 4.6% in control mango pulp. The increase of reducing sugar was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94], in goose berry fruits by Gupta VK and Mukherjee D [96].

Non-reducing sugar content of mango pulp: As given in table 4.13 and 4.14 like pH & TSS, the higher non-reducing sugar content of mango pulp was found in preservatives treated Himsagar and Langra mango pulp than those in control mango pulp. At the last edible stage the non-reducing sugar was found to be varied between 6.5% to 8.0% in preservatives treated mango pulp while that was found to be 6.3% in control mango pulp. The increase of non-reducing sugar was also reported in sweet orange cultivar of Jaffa by Chattopadhyay [94], in goose berry fruits by Gupta VK and Mukherjee D [96].

Table 4.13: Comparative Physico-Chemical data of control and preservatives treated Himsagar mango at the last edible stage

Treatments Designated mango	TSS	pH	Acidity (As citric acid)	Moisture %	Vitamin C (mg/100g)	Protein %	Fe (Iron) mg/100g	Total Sugar g/100g	Reducing Sugar g/100g	Non-reducing Sugar g/100g
Control	10	5.19	0.08	82.66	19.20	0.57	0.7218	18.60	8.90	9.70
Tetracycline 500 ppm	15	5.56	0.08	78.12	20.05	2.35	6.7327	22.24	10.80	11.44
Sodium benzoate 80 ppm	16	5.73	0.06	78.11	21.61	3.22	2.5959	23.53	11.09	11.44
Acetic acid 100 ppm	18	5.22	0.08	78.65	20.35	1.85	1.6789	23.30	11.63	11.67
Glycerine	16	5.16	0.06	80.91	19.55	2.12	1.5546	19.40	9.80	9.60

Table 4.14: Comparative Physico-Chemical data of control and preservatives treated Langra mango at the last edible stage

Treatments Designated mango	TSS	pH	Acidity (As citric acid)	Moisture %	Vitamin C (mg/100g)	Protein %	Fe (Iron) mg/100g	Total Sugar g/100g	Reducing Sugar g/100g	Non-reducing Sugar g/100g
Control	10	5.19	0.08	82.66	16.21	0.55	0.7118	9.04	3.9	5.14
Tetracycline 10 ppm	16	5.21	0.08	82.59	17.32	1.53	3.3852	11.31	4.8	6.51
Sodium benzoate 100 ppm	14	5.25	0.11	82.21	17.81	0.60	3.3079	12.42	5.6	6.82
Acetic acid 100 ppm	17	5.33	0.11	81.64	18.09	2.90	4.9801	11.38	5.1	6.28

CHAPTER V

Conclusion and Recommendations

Freshly harvested uniformly ripe mango cultivar of Himsagar and Langra were collected from the mango garden of Shatkhira and Rajshahi zone. Though mango is a delicious juicy fruit produced abundantly in our country but very limited research attentions were given to improve the physical and chemical characteristics of such by the application of preservatives at the postharvest period. The preservatives were applied on Himsagar and Langra mango and the shelf lives were observed. The results of the investigation can be summarized as follows:

i. Four cost effective preservatives such as tetracycline, sodium benzoate, acetic acid and glycerine are found out to preserve Himsagar and Langra mangoes.

ii. The above four preservatives are highly effective to control weight loss as well as to increase the shelf life of Himsagar and Langra cultivars.

iii. The preservatives also have strong capacity to retain the qualities of the mangoes.

iv. Among the treatments, tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm are the best for Himsagar mango. On the other hand, the treatments, tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm are the best treatments for Langra cultivar.

In conclusion, the relevant experimental basis has been recommended to the mango growers, wholesalers & the retailers to use the tetracycline 500 ppm, sodium benzoate 80 ppm and acetic acid 100 ppm for Himsagar cultivar. On the other hand, the treatments, tetracycline 10 ppm, sodium benzoate 100 ppm and acetic acid 100 ppm are suggested for Langra mango as these are the most effective concentrations for the reduction of postharvest losses, extension of shelf life as well as quality of Himsagar and Langra mangoes.

REFERENCES

1. Gofur, M. A. Shafique, M. Z. Helali, O. H. Ibrahim, M. Rahman M. M and. Hakim A., 1994, Effect of various factors on the vitamin C (ascorbic acid) content of some mango varieties grown in Rajshahi region. Bangladesh J. Sci. Ind. Res. Vol. 19 (3), pp. 163-171.

2. Gofur, M. A. Shafique, M. Z. Helali, O. H. Ibrahim, M. Rahman M. M. and Hakim A., 1994, Studies on the formulation and preservation of ripe mango nectar. Bangladesh J. Sci. Ind. Res. Vol. 19 (3), pp. 51- 62.

3. Prasad A. Z. and Nalini K., 1988, Investigation on post harvest physiological changes and quality parameters in mango varieties. Indian J. Hort. Vol. 45 (3-4), pp. 235-240.

4. Watson, Andrew J., 1983, Agricultural innovation in the early Islamic world: the diffusion of crops and farming techniques, 700–1100. Cambridge, UK: Cambridge University Press. pp. 72–73.

5. De Candole A., 1984, Origin of cultivated plants, Kegal Paul Trench and Co London.

6. Popnoe W., 1913, A basis for future classification of mango. Proc. Amer. Pomol. Soc. Vol. 32, p. 414.

7. Mukherjee S. K., 1949, Mango and its relatives, Sci and Cult. Vol. 15, pp. 5-6.

8. Hossain, A. K. M., Amzad and Ahmad A., 1994, A Monograph on Mango Varieties of Bangladesh. Published by Horticulture Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. p. 155.

9. Vavilov N. I., 1926, The origin, variation, immunity and breeding of cultivated plants, Chronica Botanica. Vol. 13 (1-6) , pp. 1949-50.

10. Gangolly, S. R. Singh, R. Kalyal S. L. and Singh D., 1957, The mango. Indian Council of Agricultural Research, New Delhi, p. 3.

11. Watt L. R., 1891, Dictionary of Economic Products of India, p. 5.

12. Maries C., 1902, Indian mangoes, J. Roy Hort. Soc. Vol. 26, pp. 755 -770.

13. Woodhouse E. J., 1909, Mangoes in Bhagalpur. A preliminary note. Quart. J. Dept. Agri. Bengal. Vol. 2, pp. 168-187.

14. Burns W. and Prayag S. H., 1920, Book of the mango, Bombay Agri. Dept. Bull. p. 103.

15. Popnoe W., 1941, Mango, A study in systematic pomology, Trop. Agri (BWI), Vol.18, pp.23-25.

16. Sturrock T. T. and Wolfe H. S., 1944, A Key to the Florida mango varieties. Proc. Fl. Hort. Soc. 175-180.

17. Mukherjee S. K., 1948, The varieties of mango (*Mangifera indica* L.) and their classification. Bull. of Bot. Soc. Bengal. p. 2.

18. Naik K. C. and Gangolly, S. R., 1950, A monograph on classification and nomenclature of South Indian mangoes. Supdt. Govt. Press, Madras.

19. Mukherjee S. K., 1976, Current advances on mango research around the world. Acta Hortic. Vol. 57, pp. 37-42.

20. Rahman S. H., 1990, Khadya-O-Pathya. Ashish Publications, 339, Jafarabad, Dhaka-1207. pp. 18-21.

21. Mann, S. S. Singh R. N. and Pandey, R. M., 1974, Maturity studies in Dashehari and Langra cultivars of mango. J. Hort. Sci. Vol. 3, p. 97.

22. Leley, V. K. Narayana N. and Daje J. A., 1943, Biochemical studies on the growth and ripening of Alphonso mango. J. Agr. Sci. Vol. 13, p. 291.

23. Pathak S. R. and Sarada J. R., 1974, Lipids of mango (*Mangifera indica* L). Curr. Sci. Vol. 43, p. 716.

24. Tandon D. K. and Kalra S. K., 1983, Changes in sugar, starch and amylase activity during development of mango fruit cv. Dashehari, J. Hort. Sci. Vol. 58, pp. 449-453.

25. Salunkhe D. K. and Kadam S. S., 1995, Handbook of Fruit Science and Technology. Production, Composition, Storage and Processing. Published by Library of Congress. 270 Madison Avenue, New York, USA. pp. 123-169.

26. Lakshminarayana S., 1980, Mango. Tropical and Subtropical Fruit Composition, Properties and Uses. A VI, Westport C.T. p. 184.

27. Subbarayan J. J. C. and Cama H. R., 1970, Carotenoids in three stages of ripening of mango. J. Food Sci. Vol. 35, pp. 262-265.

28. Proctor J. T. A. and Creasy L. L., 1969, The anthocyanin of the mango fruit. Phytochemistry. Vol. 8, p. 2108.

29. Piscitelli, Stephen C.; Keith Rodvold, 2005, Drug Interactions in Infectious Diseases. Humana Press. ISBN 1-58829-455-2.

30. The Pharmaceutical Century.

31. SAO/NASA ADS.

32. Wikipedia, the free encyclopedia.

33. http://chemister.ru/Database/properties-en.php?dbid=1&id=1004.

34. Sigma-Aldrich Co., Sodium benzoate. Retrieved on 2014-05-23.

35. "Skin Deep® Cosmetics Database | Environmental Working Group". Cosmeticsdatabase.com. Retrieved 2013-01-14.

36. "Sodium benzoate in Robitussin cough". Rxmed.com. Retrieved 2013-01-14.

37. CFR - Code of Federal Regulations Title 21.

38. AFCO, 2004, "Official Publication". p. 262.

39. Scientific literature reviews on generally recognized as safe (GRAS) food ingredients. National Technical Information Service. 1974. p. 1.

40. "Chemistry", volume 5, Encyclopedia Britannica, 1961, page 374.

41. IUPAC, Commission on Nomenclature of Organic Chemistry, 1993, "Table 28(a) Carboxylic acids and related groups. Unsubstituted parent structures". A Guide to IUPAC Nomenclature of Organic Compounds (Recommendations 1993). Blackwell Scientific publications. ISBN 0-632-03488-2.

42. "Acetic Acid - PubChem Public Chemical Database". The PubChem Project. USA: National Center for Biotechnology Information.

43. IUPAC Provisional Recommendations, 2004, Chapter P-12.1; page 4.

44. Ripin D. H. and Evans D. A., 2005, "pKa Table" (PDF). Retrieved19 July 2015.

45. "NIOSH Pocket Guide to Chemical Hazards #0002". National Institute for Occupational Safety and Health (NIOSH).

46. "Acetic acid". Immediately Dangerous to Life and Health. National Institute for Occupational Safety and Health (NIOSH).

47. Hosea Cheung; Robin S. Tanke; G. Paul Torrence, 2005, "Acetic Acid",Ullmann's Encyclopedia of Industrial Chemistry, Weinheim: Wiley-VCH,doi:10.1002/14356007.a01_045.pub2.

48. Suresh, B., 2003, "Acetic Acid". Chemicals Economic Handbook. SRI International. p. 602.

49. Heimo, H. Alfred R. and Dieter M., 2005, "Acetic Anhydride and Mixed Fatty Acid Anhydrides", Ullmann's Encyclopedia of Industrial Chemistry, Weinheim: Wiley-VCH, doi:10.1002/14356007.a01_065.

50. Sell, Charles S., 2006, "4.2.15 Bicyclic Monoterpenoids". The Chemistry of Fragrances: From Perfumer to Consumer. RSC Paperbacks Series 38 (2 ed.). Great Britain: Royal Society of Chemistry. p. 80.

51. Felgner and Andrea. "Titration in Non-Aqueous Media". Sigma-Aldrich. Retrieved5 June 2013.

52. Kolt, Gregory, S. Snyder-Mackler and Lynn., 2007, Physical Therapies in Sport and Exercise. Elsevier Health Sciences. p. 223.

53. Bernthsen, A.; Sudborough, J. J., 1922, Organic Chemistry. London: Blackie and Son. p. 155.

54. "NIOSH Pocket Guide to Chemical Hazards #0302". National Institute for Occupational Safety and Health (NIOSH).

55. Segur, J. B.; Oberstar, H. E., 1951, "Viscosity of Glycerol and Its Aqueous Solutions". Industrial & Engineering Chemistry Vol. 43 (9) , pp. 2117.

56. Lide, D. R., 1994, CRC Handbook of Data on Organic Compounds (3rd ed.). Boca Raton, FL: CRC Press. p. 4386.

57. Stevens A., "Preserving flowers and decorative foliages with glycerin and dye".

58. Nikolov I., "Functional Food Design Rules".

59. "Glycerin Enema". Drugs.com. Retrieved 17 November 2012.

60. "Glycerin (Oral Route)". Mayo Foundation for Medical Education and Research. Retrieved 17 November 2012.

61. Long and Walter S., (14 January 1916 – 13 January 1917). "The Composition of Commercial Fruit Extracts". Transactions of the Kansas Academy of Science 28, pp. 157–161.

62. Does Alcohol Belong In Herbal Tinctures? newhope.com.

63. Hudgens, R. Douglas, Hercamp, Richard, D. Francis, Jaime, Nyman, Dan, A. Bartoli and Yolanda, 2007, "An Evaluation of Glycerin (Glycerol) as a Heavy Duty Engine Antifreeze/Coolant Base". doi:10.4271/2007-01-4000.

64. Proposed ASTM Engine Coolant Standards Focus on Glycerin. Astmnewsroom.org. Retrieved on 15 August 2012.

65. Datta and Rasek L., 1914, "The Preparation of Allyl Iodide". Journal of the American Chemical Society, Vol. 36 (5) , pp. 1005–1007.

66. http://www.reagent.co.uk/blog/chemicals-in-film-20th-century-fox-orders-products.

67. Absar, N. Karim M. R. and Al Amin M., 1993, A comparative study on the changes in the physico-chemical composition of ten varieties of mango in Bangladesh at different stages of maturity. Bangladesh J. Agril. Res. Vol. 18(2) , pp. 201-208.

68. Bender A. E., 1982, Dictionary of Nutrition and Food Technology. 5th Edition. Published by Butterworth & Co Ltd. UK.

69. Singh U R., 1956, Effect of 2,4,5-trichlorophenoxy acetic acid and 2,4,5- trichlorophenoxy propionic acid on the fruit drop of mango (*Mangifera indica* L.) variety Karela Bhagulpur. Ann. Rep. Fr. Res. Sta. Sharanpur. pp. 65-68.

70. Ibrahim, M. Karim, M. R. Alam M. S. and Absar N., 2000, Efficacy of plant hormone on the control of fruit drop and their impact on the physiological characteristics of mango (*Mangifera indica* L). J. bio. sci. Vol. 8, pp. 17-22.

71. Prasad A. Z. and Nalini K., 1988, Investigation on post harvest physiological change and quality parameters in mango varities. Indian J. Hort. Vol. 45 (3-4) , pp. 235- 240.

72. Lashley D, 1984, Advances in postharvest technology and new technology in food production. Proc. Seminar. St. Augustine (Trinidad Tobago), pp. 173-183.

73. Krishnamaruthy H. S. and Subramanyam H., 1973, Pre and Postharvest physiology of the mango a review. Trop. Sci., Vol. 15, pp. 1167-1195.

74. Medlicott and Jeger M. J., 1987, The development and application of postharvest treatments to manipulate ripening in mangoes. In: mangoes-a review. Priensley, T.R. and G.A. Tucker (eds), commonwealth Sci. Coun., pp. 56-77.

75. Lizada M. C. C., 1991, Postharvest physiology of the mango-a review. Acta Horticulturae, Vol. 291, pp. 437-453.

76. Subramanyan, H. Krishnamurthy S. and Parpia H. A. B., 1975, Physiology and Biochemistry of mango fruit. Adv. Food Res., Vol. 21, pp. 223-305.

77. Chand R. and Kishun R., 1990, Outbreak of grapevine bacterial canker disease in India. Vol 29, Vitis, pp. 183-188.

78. Department of Agriculture and Fisheries, Quensland Govt. website, 03 September 2012.

79. Lashley D., 1984, Advances in postharvest technology and new technology in food production. Proc. Seminar. St. Augustine (Trinidad Tobago), pp. 173-183.

80. Bose T. K., 1985, Fruits of India-Tropical and Sub-tropical. Naya Prokash, Calcutta-6, India, p. 69.

81. Gofur, A. Shafique, M. Z. Helali, O. H. Ibrahim, M. Rahman M. M. and Alam M. S., 1997, studies on extension of post harvest storage life of mango (*Mangifera indica* L). Bangladesh J. Sci. Ind. Res. Vol. 32 (1) , pp. 148-152.

82. Meah M. B., 1992, Post harvest handling affecting mango quality and marketing in Bangladesh. 4th International mango symposium. Abstract: p. 106.

83. Rubbi, S. F. Rahman M. A. and Rahman K. Q., 1985, Studies on the processing and preservation of mango. Proc. 4th Natn. Symp. of Bangladesh Soc. Hort. Sci., pp. 138-148.

84. Yeasmin, F. Ibrahim M. and Morshed M. H., 2011, Studies on the Reduction of Postharvest Losses and Enhance the Storage Life of Mango (*Mangifera indica* L.) Cultivar of Aswina and also its quality characteristics as Affected by Plant Hormones. International Journal of Sustainable Agricultural Technology. Vol. 7(12), pp. 25-27.

85. Ranganna S., 1986, Handbook of Analysis and Quality Control for Fruit & Vegetable Products. Tata McGraw-Hill Publishing Company Lit. New Delhi. p. 1101.

86. Jayaraman. J., 1981, Laboratory Manual in Biochemistry. New age International Lit. New Delhi. pp. 180.

87. Loomis W. E. and Shull C. A., 1937, Methods in Plant Physiology. McGraw Hill, New York.

88. Miller G L., 1959, Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal . Chem. Vol. 31 (3) , pp. 426-428.

89. Bessey O. A. and King C. G., 1933, The distribution of vitamin C in plant and animal tissues and its determination. J. Biol. Chem. Vol. 103, pp. 687- 698.

90. Wong S. Y., 1923, The use of persulfate in the estimation of Nitrogen by the method of Kjeldahl. J. Biol. Chem. Vol. 55, pp. 427-430.

91. Wong S. Y., 1928, Colorimetric determination of iron (Fe) and hemoglobin in blood, J. Biol. Chem., Vol.77, pp.409-412.

92. Anonymous, 1980, AOAC. Official Methods of Analysis, 13th Edition, Association of Official Analytical Chemist, Washington D C, USA.

93. Wasker D. P. and Masalkar S. D., 1997, Effect of hydro-cooling and Bavistin dip on the shelf life and quality of mango during storage under various environments. Acta Horticulturae, Vol. 455, pp. 687-695.

94. Chattopadhyay, N. Hore J. K. and Sen S. K., 1992, Extension of storage life of sweet orange (Citrus sinensis Osbeek) CV Jaffa. Indian Journal of Plant Physiology, Vol. 35 (3) , pp. 245-251.

95. Parthasarathy, V. A. Medhi R. P. and Gohsh S. P., 1983, Effect of certain post harvest treatments on ripening and quality of tomato fruits. Progressive Horticulture Vol. 15 (1-2) , pp. 119-121.

96. Gupta V. K. and Mukherjee D., 1982, The influence of wax emulsion, morphactin and gibberellic acid on the storage behaviour of India goose berry fruits. Scientia Horticulture Vol. 16 (2), pp. 156-162.