DEHYDRATION, PACKING AND STORAGE STUDIES OF FRUITS (BANANA, JACK AND MANGO)

By

M. KUBER SINGH

THESIS

Submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I hereby declare that this thesis entitled "Dehydration, packing and storage studies of fruits (banana, jack and mango)" is a bonafide record of research work done by me during the course of investigation and this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any university or society.

M. Kuber Singh

Vellanikkara,
25th February, 1983.

CERTIFICATE

This is to certify that this thesis entitled "Dehydration, packing and storage studies of fruits (banana, jack and mango)" is a record of research work done independently by Shri. M. Kuber Singh under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, fellowship or associateship or other similar title of any University.

Prof. V.K. Damodaran

14/3/83

Vellanikkara,

25th February, 1983.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Shri. M. Kuber Singh, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Dehydration, packing and storage studies of fruits (banana, jack and mango)" may be submitted by Shri. M. Kuber Singh in partial fulfilment of the requirement for the degree.

Prof. V.K. Damodaran,
Chairman

Achamma Ommen
Member

K. Leela
Member

Dr. K.C. George,
Member.

To My Wife and daughter

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Introduction

INTRODUCTION

Fruits and vegetables are important components of our daily diet but being highly perishable it is difficult to store them for more than 3-5 days. It is estimated that Rs.300 (Rupees three hundred) crores worth of the country's production of fruits and vegetables production is lost annually for want of adequate processing and marketing arrangements. Although production of fruits and vegetables has risen substantially during the last decade, about 25 to 40% cannot be utilised due to the lack of proper processing and storage. In the case of many fruits, there is a glut in the market during the harvesting season while there is surplus and low cost in the on season. In either case the producer is the loser and there is no incentive to produce more. The solution for this is to adopt some methods of preservation which will prevent further spoilage. There are several methods of preservation of fruits and vegetables, drying or dehydration is perhaps the cheapest among them. It involves the removal of the moisture content to such a level that the micro-organism cannot survive for any length of time and the enzymes are made inactive. It is one of the oldest methods of food preservation known to man and one of the newest. The value of dehydrated foods under wartime conditions was invaluable as it made easy to carry to mountain areas in the fighting front by making them light in weight. Sun-drying still accounts for the major part of dried fruits consumed in the world today and mechanically-dehydrated fruits are produced in small amounts as compared to them, but the quantities of the latter are rising rapidly. Much has been done to improve the quality of dehydrated foods. Among the things that led to improvements are the use of raw material that is better adapted to the requirements of dehydration, new processing technology, improved equipment, lower moisture content in finished product, better control of sulphur application and improved packaging (Van Arsdel and Copley, 1963; McBean, 1971; Potter, 1973).

At present most of the dried fruits other than prunes, are dried in the sun but dehydration is rapidly increasing in importance because of its following advantages.

1. Dried fruits have an almost unlimited shelf-life under proper storage condition.
2. Vitamin losses are not greater in dehydration than with other preservation methods.
3. Transportation, handling and storage costs are substantially lower when compared with that of similar foods. Shipping and handling weight is reduced by 90%.
4. Seasonal variation in product quality is either absent or at a minimum in low moisture fruits.

5. They utilize the most economical and disposable form of packaging. The two major considerations in packaging dried fruits are the exclusion of moisture and oxygen. Metal cans, plastic bags and laminated bags and boxes effectively limit the passage of moisture and oxygen.

6. In seasons of early rains, the use of dehydrator prevents loss through rain damage.

The shelf-life of a dehydrated fruit product is influenced to a large extent by the packaging which must conform to certain special criteria. These are (a) protection of the dehydrated product against moisture (Heiss and Eehner, 1971), light, air, dust, microflora, foreign odor, rodents, etc., (b) strength and stability to maintain original container properties through storage, handling and marketing, (c) size, shape and appearance to promote saleability of the product, (d) composition of the container must be approved for use in contact with foods and (e) cost must be reasonable.

The hygroscopic nature of low moisture fruit tissue makes it imperative that special precautions be taken against moisture absorption. The low-moisture products must be packaged as soon as possible after removal from the dehydration and hermetically sealed containers are required to prevent absorption of moisture with subsequent caking and loss of quality during extended storage. Very little research on these aspects have been done so far. Therefore, research on drying, packaging and storage of three common fruits was conducted at the College of Horticulture, Vellanikkara with the following objectives:

1. Preparation of dehydrated fruits (banana, jack and mango).
2. Packing the dehydrated fruits in different types of flexible containers.
3. Analysis of the nutrient content of the dried fruits in the case of different types of packages.
4. Pest and disease problems of the stored products.

Review of Literature

REVIEW OF LITERATURE

Many of the food materials, raw as well as improperly processed will spoil within a few days and every efforts have been tried to prevent that spoilage by different methods of processing and storage. Among the different methods of food processing and preservation, drying or dehydration has been successfully adopted from very early times by our ancestors in the case of many fruits and vegetables.

Preservation by drying has certain advantages as well as disadvantages as compared to other methods. It is simple and comparatively cheap and can be adopted in the case of certain fruits and vegetables. Heat processing is very common in the case of many food products, but is costly and the loss of vitamins and flavour are considerable. Several scientists have worked a lot in adopting dehydration as a method of effective processing and preservation of several food products and the same are briefly reviewed in the following.

1. Raw materials - Production and Processing

1.1. Fruits and other raw materials

Not all the varieties of fruits are suitable for canning or preservation. In terms of structural and chemical definition, fruit for drying should have reached that stage when they are still firm enough to withstand harvesting and processing practices without brushing and breakage of the skin, whereby enzyme systems are stimulated to produce browning. Starch should be converted to sugar and the sugar-acid ratio should be near at its highest level. Flavour volatile should also be near their peak concentration. Soluble solids generally increase as fruit matures, but it is not always reliable to compare the changes in one season with those of another, district to district and even orchard to orchard variation may be large.

Considerable knowledge concerning the role of constituents in determining the suitability of a particular variety of fruit for dehydration and of the changes occurring during drying and storage have been well brought out in the investigations on the effect of maturity. As early as (1915) Bioletti reported that yield of raisins were influenced by the maturity of the grapes when harvested for drying. This was confirmed by Cruess et al. (1920); Cruess and Christie (1921); Christie and Barnard (1925) and Jacob (1942).

2. Preparation for drying

2.1. Pre-drying treatment

Pre-processing treatments applied to fruits before they are dried are usually necessary to ensure a reasonably short drying time and to limit heat-induced deteriorative changes to the minimum.

Mrak and Phaff (1943) reported that, unblanched dehydrated fruit was opaque in appearance whereas the blanched fruit had a desirable transluent appearance. They found, however, that while steam blanching of cut fruits (except apple) was feasible, blanching of whole fruits such as prunes and grapes was not because of loss of syrup. Lazar et al. (1963) introduced blanching after a preliminary drying in a dry-blanch-dry process, this reduced the syrup loss so that blanching could be applied in grapes.

3. Sulphuring

Probably the most significant pre-treatment applied to many fruits before drying is that commonly known as "sulphuring", i.e., the application of sulphur dioxide or sulphite solutions to fruits. The limit of SO2 concentrations in dried fruit is usually in the range of 2000 to 3000 ppm for cut fruits. Such limits are invariably specified as total SO2, but Joslyn and Braverman (1954) pointed out that the preservative must exist in both free and combined form, the relative proportions of these are determined by such factors as the composition of the fruit, its pH and its temperature during drying. McBean et al. (1965) showed that as little as 5% might be retained under slow drying conditions and upto 40% if water removal was very rapid. Embs and Markakis (1965) reported that sulphite prevented oxidation of cathecol by mushroom polyphenolase by combining with the O-Quinons and preventing their condensation to malanin. Markakis and Embs (1966) subsequently reported that ascorbic acid facilitates sulphite inhibition of phenolase. Stanley (1968) found that Sucrose inhibited the phenolase of apples, dates, grapes, figs, and prunes which were dried without any enzyme inhibition darken during water removal and were acceptable in this form. He also reported that sulphur dioxide applied principally to prevent non-enzymatic browning during drying and storage was however, widely used and was highly inhibitory to the polyphenolase.

McBean _et_ _al_. (1967) reported that the free S02 contents diminished throughout the whole drying period, whereas levels of combined S02 remained relatively unchanged and reached 80-90% of the total in the dried fruit. He showed that between 10 and 20% of the total S02 absorbed by apricot and peach tissue was in the combined form at the conclusion of sulphuring and that the rate of combination was linear. Chan and Cavaletto (1978) studied the effect of S02 on the quality of the papaya leather. He reported that drying rate was decreased when high S02 (sulphur dioxide) level was given and that the presence of S02 protected against darkening at high drying and strong temperature. Khurdiya (1980) reported that sulphuring at the rate of 15 g/8 kg of fruit (3 hour burning) was considered optimum. Kitson and McGreger (1982) reported

reported that addition of apple puree (400 ppm SO2) before drying will retard off flavour formation in the dried product stored for 2 years at 20°C in polythene bags.

4. Drying

4.1. A. Moisture transfer

4.1.1. Physical

Theoretical aspects of dehydration have been considered by Van Arsdel and Copley (1963). The most important operation in dehydration is the mass transfer of moisture. In living fruit tissues, water loss largely occurred by diffusion from the cells to the intercellular spaces, followed by diffusion, probably as vapours, from the intracellular spaces through pores (lenticels and stomata) in their skin (Fogg, 1965).

Results of studies by Cruess *et al.* (1920), Wiegand (1924) and Christie (1926) for prunes and concerned chiefly with such factors as the loading, maturity and size and shape of fruit and drying condition, need further examination using modern techniques and embracing a wider variety of fruits. The design of fruit dehydrators based on actual determination of mass and heat transfer factors were investigated in some detail for prunes by Guillou (1942). Perry (1944) reported data on heat and vapour transfer in the dehydration of prunes, including temperature and moisture distribution during dehydration. Most fruits, apples, grapes, pear and prunes have a pronounced waxy bloom which restrict the water transfer. The cuticular wax of grapes was investigated by Chambers and Possingham (1963), of apple by Meigh (1964) and of prunes by Bain and McBean (1969).

4.1.2. Biochemical

Apart from increased solids concentration due to water removal, from individual components also under that changes. Partial inversion of sucrose occurs in those fruits which contain large amounts of sucrose particularly if the acid content was also high.

Water is by far the most abundant constituent of fruits, ranging from 90% in berries down to 70% in bananas. The diffusion of water in the tissue during drying is influenced by the state of water present. In fruit tissues most of the water present may be "free" but appreciable amounts of water may be held as water of hydration by such constituents as dextrose or maltose, organic acids such as tartaric acid and tartarate. Much of bound water may be held by hydrogen bonding at particular constituents. While the concept of "bound" water has been questioned by Kuprianoff (1958), there is much evidence in its favour. Shimazu and Stirling (1961) investigated changes in cellulose and calcium pectate in model systems during dehydration and found an increase in crystallinity. Ward (1963) discussed the nature of the forces between water and the macromoleecular constituents of foods.

5. Colour changes

5.1. Enzymatic browning

Onslow (1920) reported that enzymatic browning occurred through the effect of an oxidase on a cathechol compound to form either hydrogen peroxide or a peroxide which then oxidises some other compound, the cromogen. Hussein *et al*. (1942) reported that group peroxidase was responsible for darkening of raisins. Chari *et al*. (1948) considered peroxidase to be involved in the darkening of prunes. Joslin and Ponting (1951) reported that Caffeoyl-shikimic acid is responsible for darkening the dates. Pridham (1963) also found that 3,4-dihydroxyphenyl ethalamine was responsible for darkening in banana.

Gincarevic and Hawker (1971) reported that browning of Sultana (grape) during drying under mild condition was caused by the action of o-diphenol oxidase on substrates released from the skin tissue.

5.2. Non-enzymatic

5.2.1. Browning (the Maillard reaction) and other colour changes

The condensation of reducing sugar with amino acids, a process accelerated by heat, was responsible for much of the darkening, which occurs in fruits tissue during storage, it was also probably responsible for the major part of the darkening occurring during the drying of fruits. Possible courses of the browning reaction have been considered in a number of reviews, notably by Hedge (1953) and by Reynolds (1963) who suggested that the organic acid present in the fruit may participate in the reaction. Karel and Nickerson (1964) reported that the moisture content and temperature of storage had great influence on the degree of non-enzymatic browning. The mechanism of the inhibition of the Maillard reaction by SO_2 was investigated by Song and Chichester (1966). They reported that bisulphite inhibited the reaction prior to the one giving steady state browning, and suggested that an active form of bisulphite combined with an intermediate compound involved in the overall browning reaction. The chemistry of the bleaching of anthocyanins by SO_2 was investigated by Jurd (1964) and by Timberlake and Bridle (1967). Meweeney et al. (1969) reported that bisulphite reaction with sugar intermediates to form stable sulphonated product was responsible for enzyme inhibition process.

6. Sugars

Thompson and Schrader (1949) reported that during storage chemical changes do occur including loss of SO_2, hydrolyses of starch and increase in sugars (reducing and total sugar).

They observed that there was increase in sugars in case of apple. They also reported that starch content was decreased throughout the storage period irrespective of package could be ascribed to the hydrolyses of starch. Kikon (1977) observed in dried apple an increasing trend in reducing and total sugars during storage. Rao and Roy (1980) reported that reducing sugars increased with the increase in temperature of storage.

7. Acidity

Kikon (1977) reported that there is decreased in acidity during storage. This could be probably due to disappearance of SO_2 from the product. Rao and Roy (1980) reported that acidity increased with the increase in temperature of storage.

8. Taste and flavour

The flavour of fruits are mainly due to volatile components spread throughout the tissue. Most fruits which are dried contain appreciable amounts of organic acids, that contribute to their flavour and taste characteristics. The presence of SO_2 enhances the retention of vitamin C to the extent that 50% of the original content may be retained in the dried product (Morgan and Field, 1929) on the other hand, thiamin is totally destroyed by SO_2 (Morgan *et al.*, 1935).

9. Packaging

Amin and Bhatia (1962) mentioned permeability of polyethylene bag to moisture vapours. However, gain in moisture was comparatively more in paper bags as compared to polyethylene bags which may be because of the more permeability to moisture of the paper bags as compared to polyethylene bags. Saigo and Matsui (1968) studied storage stability of mandarin orange in syrup under the influence of white lamp, mercury, sun with various plastic films eg. polythene, cellophane, polyster and laminates as packaging material. They reported that storage in darkness gave better stability. Davis (1970) discussed the measurement of gas and vapour permeability and taining properties of aluminium foil, paper, cellulose and polypropylene. Tuomy (1970) reported that flexible containers are the most promising packages for freeze dried foods. McCarron (1972) reported that the most satisfactory packaging material is cellophane and cellophane base laminates with respect to aroma.

Day (1973) studied the use of foil packaging and protection afforded to confectionary product against moisture absorption aroma and odour and dirt. When the type of plain and laminated foil available and their handling properties are considered. The polyethylene foil laminate was the most moisture and odour resistant flexible film. Lane (1973) reported that the foil containers not only protect the product from physical damage but also play an important part in the processing of the product. Anon (1976) discussed the outlook for prices, steps to be taken to help overcome problems due to material supply shortage and situation for cellophane, polyethylene, polypropylene and polyster. Kumar et al. (1976) reported the range of packaging films and laminates for water vapour transmission rate, tensile strength, elongation, brusting strength, tearing resistance and grease resistance. Adsulf and Anand (1977) reported that among different types of plastic containers used LDPE and HDPE tended to lose SO_2 most rapidly followed by polyvinyl chloride and glass irrespective of the product and the storage temperature. Mahadeviah et al. (1977) reported that for long term storage of about 8-10 months and to withstand physical and environmental hazard, LDPE 400 gauge are quite suitable in offering a desired protection for pulses of unit packs of 500 g. However, for short-term storage of about 3-4 months, 200 gauges of LDPE film is quite adequate under all conditions of storage. Anon (1979) discussed the use of cellophane and polypropylene for flexible packaging. Amba Dan and Adsule (1979) studied both preservation of mango pulp in HDPE container stored at room temperature (21°-34°C) over 12 months and were assessed for physico-chem. properties. Balasubramanyam and Anandaswamy (1979) reported the characteristics of the packages required to prevent rancidity and moisture increased and comparative advantage of different types of packaging. Andres (1980) studied packaging trends including retort pouches and advantage of flexible packaging. Hornberg (1980) reported the vitamin C content of orange juice drink packed either in glass and flexible packaging. Rao and Roy (1980) reported that ideal moisture to have storage stability was found to be 15% or a little more with a relative humidity between 63 to 70% in dehydrated papaya. Schmidt and Bauber (1980) studied the insect proof packaging with the laminated film. They found that the foils were resistant against invaders but not penetrators. Hohn (1981) studied the characteristics of several types of packaging material i.e., weight, suitable temperature, transpiracy, organoleptic properties, flexibility and O_2/CO_2 permeability. Mahadeviah (1981) discussed the recent developments in the Federal Republic of Germany on the packaging materials with respect to metal, glass and plastic containers. Introduction of aluminium container, heat sterilisable glass container and plastic laminate and semi-rigid containers have been highlighted. Satyavati Krishnamkutty et al. (1981) reported that banana chips fried in fresh coconut oil and packed in 300 gauge HDPE and 400 gauge LDPE bags packaging are satisfactory upto two months. Tuchy (1981) studied the new type of LDPE, linear LDPE which may have application in the food industry.

10. Storage

The deteriorative changes in flavour, texture and colour initiated during drying and possibly during pre-drying procedures continue when the fruit is held or stored after drying. The changes in colour which occur in dried fruits during storage have been the subject of extensive investigation (Mackinney, 1946). Stadtman *et al.* (1946) reported that in absence of oxygen the rate of darkening of dried apricots increased with decrease in moisture content over the range 40-10% and reached a maximum at moisture content between 5 and 10%. Barger *et al.* (1948) suggested that the best temperature for the storage of dried fruits generally was 0°C at a relative humidity 55%. Thompson and Schrader (1949) recommended 0.8°C for dried apples. Miller and Chichester (1960) reported that the crystalline deposits on prunes and figs contain glucose and fructose, with traces of citric acid, malic acid, lysine, asparagine and aspartic acid. Maier and Schiller (1961) reported on some chemical changes occurring during storage of Deglet Nair Dates at 49°C. Darkening was found to be the combined result of both oxidative (10-20%) and non-oxidative browning. Acker (1962) reported that the moisture level at which dried fruit would have the desired storage life depends on the reduction of available moisture below 25-30%, at which level microbial growth and activity and tissue enzymes activity became appreciable. Maier and Metzler (1965) reported data on the changes occurring on date polyphenols during maturation and storage and their relation to browning. The flavours and caffeoyl-schikimic acid were found to undergo the greatest decrease during maturation and browning. The phenolics were most susceptible to enzyme browning. Bolin and Boyle (1967) reported that a higher moisture levels chemical preservatives must be used, alternatively, the micro-organism capable of developing may be destroyed by heat. Sharma *et al*. (1974) studied the production and storage behaviour of Spry dried mango powder. They reported that during a storage period of 1 year at room temperature 31 ± 1°C there was no perceptible change in colour, flavour and reconstitution of the product but there was progressive increase in the free-fat content, volatile free-fatty acids and acidity values. Ramanuja and Jayaraman (1980) reported that the banana slices treated with 300 ppm SO_2 and packed in flexible laminate pouches remained acceptable upto 9 months at room temperature and 4 months at 37°C. With 500 ppm SO_2 the shelf life of the slices was 12 months at room temperature and 6 months at 37°C.

11. Rehydration

The condition of influencing absorption of moisture by dried fruits were investigated by Nichols (1935) for moisture increase during processing of dry prunes in boiling water. Nury *et al*. (1963) developed an improved procedure for rehydration using steam and boiling water followed by a short-immersion in cold water and applied it to fig and raisins as well as prunes. Sterling (1963) observed that dried cell-walls are not very permeable to water, suggesting a denaturation of the cell wall material. Nury and Salunkhe (1968) showed that cell walls shrunk during drying and some breakage occurred. The porous nature of vacuum dried material permits rapid and more complete reconstitution then the collapsed nature of air dried fruit. Vollink *et al.* (1971) reported that low moisture strawberries can be produced with a modified freeze drying process which yields fruits capable of rehydration in milk within 30-90 sec. Anon (1977) reported that rehydration of cabbage to 75% of fresh weight takes 1 hour but better results are obtained with 3 h. rehydration at room temperature. The rehydrated cabbage maintain a crips texture. Solms *et al.* (1978) reported that salt-treated vegetables had a higher degree of reconstitutions and were softer in texture than water blended vegetables. After 12 months storage periods, salt-treated samples were superior in colour and flavour to water blenched and sulphited samples as judged both analytically and sensorily. Khurdiya (1980) reported that reconstitution of dried ber is achieved by soaking for 2 hours and boiling for 5 min. in water and were organoleptically acceptable after 6 months of storage.

12. Product

Roy and Singh (1952) reported that mango powder is better than the slices because of its ready form for use in any preparation like the pulses soups or vegetables. Strashan and Talburt (1954) reported that citrus product are mostly dehydrated as juice produced only. Orange crystals are prepared using a vacuum process in which orange concentrates of 58°B is the starting material. Robert and Faulkner (1965) reported that low moisture apricot products are utilized in dry turn over, pie or tart filling mixes, or in fruit cocktail type mixes in combination with other dehydrated fruits to be consumed as stewed fruit. Flakes can be formed and the low moisture apricot flakes may be used as a cereal additive. Prabhakar Bhat et al. (1974) reported that curry mixes based on cabbage-potato, Frenchbean-potato, peas-potato combination has good acceptability as regards flavour, colour and reconstitution properties both initially and after storage for one year under ambiant air condition and at 37°C. Gangopadhyay et al. (1976) reported that mango powder could form base material for chutney and beverages. Simek (1978) reported that the dried potatoes maintain the specific aroma and flavour of the fresh potato as well as maximum of their original nutritional value.

Materials and Methods

MATERIALS AND METHODS

These investigations were carried out in the College of Horticulture, Vellanikkara, during the year 1981-82. During 1981-82 dehydration was done during April-May. Three different crops viz., banana, jack and mango were taken up for the studies.

1. Preparation of the fruits

1.1. Banana: "Nendran" variety banana, which is very popular in this part of the country was selected for dehydration studies. Fruits which have just started ripening were selected and their fingers were hand peeled and sliced with the help of stainless steel knife. The thickness of the slices was maintained at a range of 2.5-3.5 mm. Thickness was measured with the help of a vernier calliper.

1.2. Jack fruit: "Varika" type early variety was selected for the studies. Uniformly mature fruits were selected and kept at room temperature for 3 (three) days for ripening. Fruits were peeled off with the help of stainless steel knife. Bulbs were taken out and the seeds were removed and the flakes were made into small pieces by hand. Thickness ranged between 2.0-2.5 mm.

1.3. Mango: "Neelum" variety was choosen and uniformly mature fruits were harvested and utilized for the study.

Fruits were peeled off with steel knife and sliced into pieces of 2.5-3.5 cm in thickness.

The following physical and chemical characters were recorded before the fruits were prepared for dehydration.

1. Physical characters

1.1. Banana

1.1.a. Average weight of a finger

1.1.b. Pulp to peel ratio

1.2. Jack fruit

1.2.a. Average weight of the whole fruit

1.2.b. Bulb, peel, core ratio

1.2.c. Bulb to seed ratio

1.3. Mango

1.3.a. Weight of whole fruit (average of 10 fruits)

1.3.b. Peel to pulp (including stone) ratio

1.3.c. Pulp to stone ratio

2. Chemical characters

The following chemical components were analysed after taking appropriate samples.

2.1. Moisture

2.2. T.S.S. (total soluble solids)

2.3. Sugars (reducing and total)

2.4. Titrable acidity

3. Pre-drying treatments

Before drying the prepared fruits were soaked in water containing 2000 ppm potassium metabisulphite solution for 2 (two) hours and the pulp was drained off the treatment solution.

4. Drying of fruits

Drying of the fruits was done by any one of the following methods.

i) Sun-drying

ii) Drying by mechanical method

The thickness of the spread for both methods was 1 kg/sq.ft. For tray dehydrator, temperature was adjusted at 65 $\pm$ 5°C. Drying time of the different fruits was also calculated.

5. Packing

Dried fruits were packed

i) in powder form

ii) as chips

Powdering was done with the help of grinder. 25 g both in powder form and chips were packed separately in the following packing materials.

5.1. Craft-paper bag (T_1)

5.2. Butter paper bag (T_2)

5.3. Polythene bag (150 gauge) (T_3)

5.4. Polypropylene bag (100 gauge) (T_4)

6. Storage studies

The packed materials in different packets viz., craft paper bag, butter paper bag, polythene bag and polypropylene were stored at room temperature (28-30°C). Half of the load was kept in iron wire basket press to protect from the rats. Remaining half were kept inside a steel trunk. The following physical and chemical characters were recorded after 50th, 70th, 90th, 110th, 130th, 150th, 170th and 190th day of storage.

6.1. Physical characters

6.1.1. Organoleptic test

6.1.1.a. Reconstitution of chips in syrup of different strength.

6.1.1.b. Preparation of 'Payassam' using reconstituted fruit powder.

6.2. Chemical characters

The following important components were analysed chemically on moisture free basis.

6.2.1. Moisture

6.2.2. T.S.S.

6.2.3. Sugars (reducing, total)

6.2.4. Titrable acidity

6.1.1.a. Reconstitution of dehydrated foods in sugar syrup

Sugar syrup of different strength viz., 20%, 25%, 30% and 35% was prepared for reconstitution of banana, jack and mange chips. 50 g samples were soaked in 250 ml boiled syrup for 30 minutes and syrups were drained off and reconstitution ratios were calculated. Organoleptic tests were carried out by a panel of seven judges and they rated the quality of the fruits by assigning ranks, adopting the rating given by Singh (1967).

Category	Marks
Poor	1.01
Fair	1.01 to 2
Good	2.01 to 3
Excellent	3.01to 4

The average score was worked out for each sample from the rating made by the panel of judges and comparison made. The palatability rating (score) was considered as the criteria of judging the quality of the product.

1.1.b. Preparation of 'Payassam'

Payassam from the stored powder of banana, jack and mango were prepared after different time intervals of storage. Following were the recipe of the products.

1. <u>Banana</u>

Water	- 1200 ml
Jaggery	- 300 g
Fruit powder	- 100 g
Coconut milk	- from a medium size nut
Cashewnut	- 25 g
Raisin	- 25 g
Spices (cardamom, clove etc.)	- for flavouring

2. <u>Jack fruit</u>

Jaggery	- 250 g
Water	- 1200 ml
Fruit powder	- 150 g
Cashewnut	- 25 g
Raisin	- 25 g
Spices	- for flavouring
Coconut milk	- medium size nut

3. <u>Mango</u>

Water	- 1200 ml
Jaggery	- 350 g
Fruit powder	- 100 g
Coconut milk	- from a medium size nut
Cashewnut	- 25 g
Raisin	- 25 g
Spices	- for flavouring

Jaggery was dissolved in 500 ml of water and boiled for 2 minutes in a stainless steel pan. Then filter using muslin cloth to remove impurity from the jaggery. Then add remaining quantity of water and keep for boiling 5-10 minutes. Cashewnut was fried in 10 g of butter. Raisins were added in the early stage of boiling water. Powder was added when water had just started boiling. Then coconut milk was added and kept for boiling for about 2 minutes. Then cashewnut and spices were added and then the container was taken out from the fire and kept for cooling.

Organoleptic test was performed same as in the reconstitution of chips.

6.2. Chemical characters

For determining T.S.S., dried powder was diluted with distilled water at the rate of 1:2. Then it is mixed in a mixer (grinder) for one minute. Then T.S.S. was determined using a pocket refractometer. Sugars (reducing and total sugars) and titrable acidity were estimated adopting the standard procedures prescribed by A.O.A.C. (1980) and expressed as percentage. In order to determine the moisture content, a weighed quantity of the dried samples i.e., 10 g was taken and dried in hot air oven at 70°C till there was no further reduction in weight. The moisture content was worked out as the loss in weight as a result of drying and expressed in percentage.

7. <u>Statistical analysis</u>

Data relating to chemical analysis were analysed statistically by applying the technique of variance in completely randomised design (C.R.D.) with four replications and the significance was tested by 'F' test and compared the treatment means (Panse and Sukhatme, 1957).

Results

RESULTS

Dehydration of fruits and vegetables brings about major changes in the physical and chemical characteristics of banana, mango and jackfruit. The studies made on these aspects are presented below:

Physical characteristics viz., average weight of the finger, pulp to peel ratio (in case of banana), average weight of the fruit (both in mango and jackfruit), peel, stone and pulp ratio, stone and pulp ratio of mango and seed to bulb ratio and bulb to waste (core, rind, etc.) of jackfruit were determined and the data are shown in Table 1.A.

Chemical characteristics like moisture, T.S.S., total sugar, reducing sugar and acidity of banana, mango and jackfruit are depicted in Table 1B. It is evident from the table that all the three fruits used in the present investigation contained moisture within the range of 70-85%, indicating their moisture rich nature.

1. Pre-drying treatments of the fruits

Ratio of fresh fruit weight to that dipped in KMS solution for 2 hours, drying time and drying ratio of banana, mango and jackfruit are presented in Table 2. It may be seen from the table that the dip treatment increased the fruit weight in all cases. The increase in weight was the maximum for banana (1:1.33) followed by jack (1:1.23) and mango (1:1.09). Comparison of this observation with the moisture data in Table 1 showed a negative relationship, the trend being, lower the initial moisture content of the fruit, higher is the weight picked up during the dipping process.

2. Drying of fruits

2.1. Sun drying: It was observed that sun drying was not feasible under Vellanikkara condition. The material remained moist and pulpy even after 25 days of drying. Data in this regard in relation to rainfall, sunshine hours, maximum and minimum temperature and relative humidity are presented in Appendix I.

2.2. Mechanical drying: It may also be seen from the Table 2 that the time taken for drying was the maximum in banana (87 hours) followed by jack (83 hours) and mango (80 hours). A perusal of this observation indicated that the drying time is directly related to the fruitweight after dipping but not with the initial moisture content (Table 1).

Observations on the drying ratio indicated that the drying ratio was minimum in the case of banana while it was maximum in mango, indicating a close relationship to the initial moisture content.

2.3. Browning during drying: Browning of the product was observed during dehydration at the end of 48 hours.

Table 1. Physico-chemical characteristics of banana, mango and jackfruit during dehydration

Particulars	Banana	Mango	Jackfruit
A. Physical characters			
Average weight of a finger	17 5 g	..	..
Pulp to peel ratio	1.8:1	..	..
Average weight of the fruit	..	37 0 g	57 00 g
Peel, stone and pulp ratio	..	1:1.1:6.4	..
Stone to pulp ratio	..	1:6.1	..
Seed to bulb ratio	..	..	1:4.5
Bulb to waste (seed, core, peel) ratio	..	..	1:2.6
B. Chemical characters			
Moisture	70%	85%	75%
T.S.S.	12%	7.2%	12%
Total sugar	10.2%	7.04%	9.3%
Reducing sugar	5.29%	3.4%	3.2%
Acidity	0.45%	0.92%	1.02%

Table 2. Ratio of pre-drying of fresh fruit and dipped fruit (in 2000 ppm KMS soln.) in dehydrated fruits

Particulars	Banana	Mango	Jackfruit
Ratio of fresh fruit and the dipped fruit after dipping for 2 hrs at 2000 ppm KMS	1:1.33	1:1.09	1:1.23
Drying hours to bring down to minimum moisture level	87 hrs	80 hrs	84 hrs
Fresh to dried fruit weight ratio	4.1:1	6:1	6.05:1

3. Storage studies

3.1. Effect of storage conditions on the quality of dehydrated materials during storage

It was observed that the dehydrated materials (chips and powder) packed in T_1 (craft paper bag), T_2 (butter paper bag), T_3 (polythene bag) and T_4 (polypropylene bag) and stored in open atmosphere were subjected to serious quality deterioration by fermentation. The materials stored by this method showed the first sign of fermentation by 50th day of storage. When the packed dehydrated materials were stored inside a steel trunk, there was no damage to the product and it remained acceptable even at the end of 190 days.

Accordingly the samples were stored inside an iron steel trunk for further studies.

3.2. Effect of packing materials in the chemical composition of dehydrated materials during storage

3.2.1. Moisture

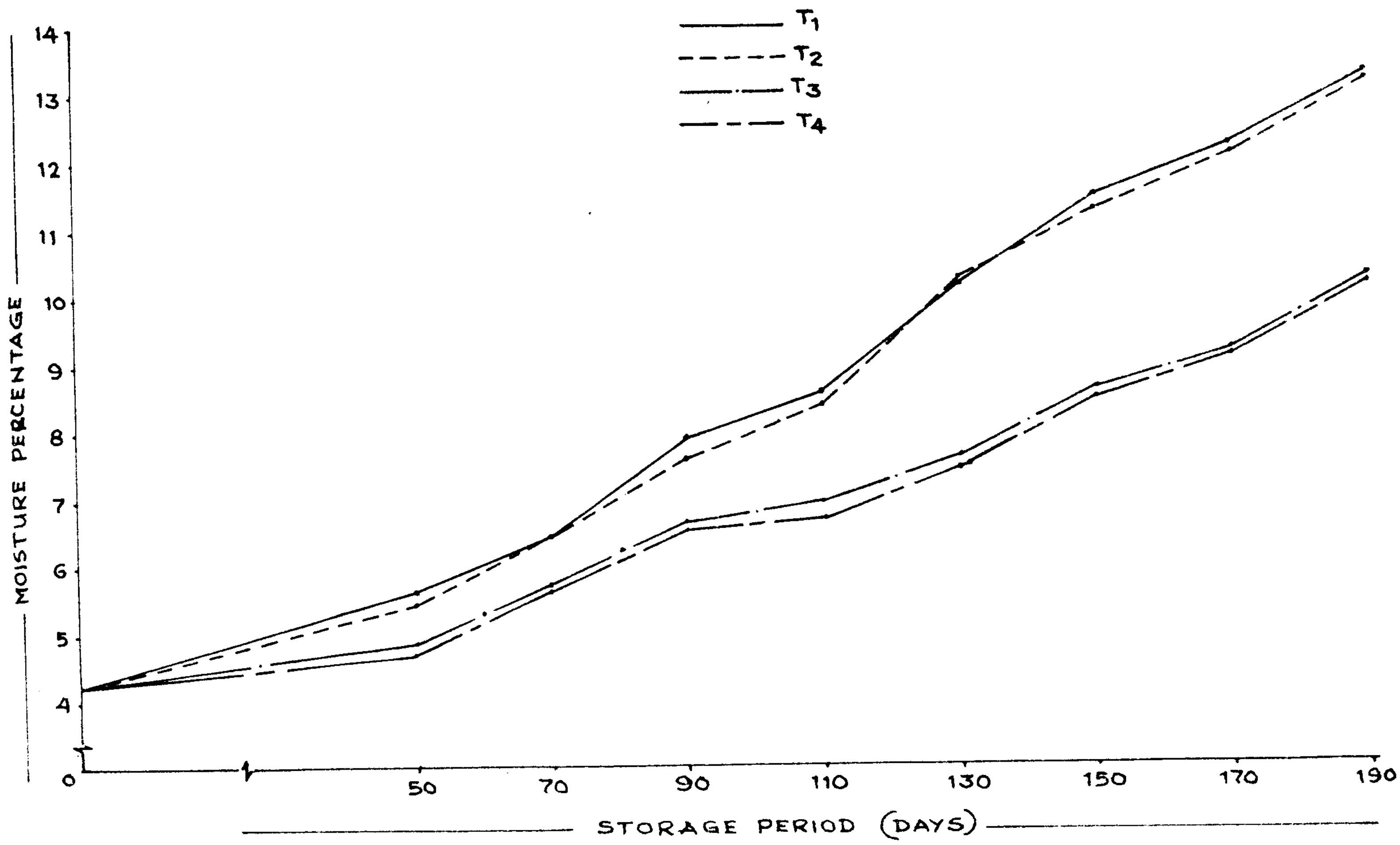
3.2.1.a. Banana: Moisture content in banana powder, stored in different packing materials is presented in Table 3. and its ANOVA in Appendix II. Figure 1 depicts the moisture content at different periods of storage graphically. The initial moisture content i.e. at zero storage was 4.14%. The moisture content after 190 days in storage was recorded as 13.2% in T_1 (craft paper bag), 13.16% in T_2 (butter paper bag), 10.18% in T_3 (polythene bag) and 10.17% in T_4 (polypropylene bag).

Table 3. Moisture percentage of banana powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	4.14	4.14	4.14	4.14	..
50	5.63	5.42	4.81	4.66	0.43
70	6.41	6.41	5.68	5.65	0.14
90	7.85	7.58	6.63	6.53	0.91
110	8.51	8.31	6.94	6.65	0.21
130	10.13	10.14	7.55	7.40	0.12
150	11.37	11.23	8.53	8.48	0.1
170	12.17	12.04	9.16	9.13	0.1
190	13.2	13.16	10.18	10.17	0.89

T_1 = Craft paper bag
T_2 = Butter paper bag
T_3 = Polythene bag
T_4 = Polypropylene bag

Fig-1- MOISTURE PERCENTAGE OF BANANA POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD



The minimum change in moisture content among different packing materials tried in the experiment was T_4 while T_3 was on par with it. Thus T_4 and T_3 ranked best among the different packing materials tried. The data also indicated that a similar trend was maintained throughout the period of storage.

3.2.1.b. Mango: The dehydrated fruit material was dried to the level of 5.05% of moisture and changes detected thereafter during storage are given in Table 4 and Fig.2, with its ANOVA in Appendix II. The rate of absorption of moisture was highest in T_1 in which 13.86% moisture was recorded after 190 days of storage. The minimum change was detected in T_4 in which it was 11.24% after 190 days of storage. T_2 and T_3 recorded 13.81 and 11.30% moisture respectively. T_1 and T_2 were significantly different from T_3 and T_4 in moisture absorption. The analysis after 50 days of storage indicated that all the treatments are significantly different while after 70 days of storage difference between T_3 and T_4 was not significant.

3.2.1.c. Jackfruit: The moisture content in the dehydrated fruit samples (average of 4 replications) at different period of storage are presented in Table 5, Fig. 3 and its ANOVA in Appendix II.

The zero storage moisture content of the samples was 6.16%. There was a gradual increase with the advance in the

Table 4. Moisture percentage of mango powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	5.05	5.05	5.05	5.05	..
50	6.33	6.22	5.82	5.72	0.06
70	7.68	7.49	6.60	6.50	0.1
90	9.14	9.12	7.75	7.74	0.15
110	10.59	10.39	8.44	8.4	0.17
130	11.26	11.25	9.14	9.13	0.43
150	12.21	12.21	9.91	9.82	0.12
170	13.11	13.09	10.75	10.64	0.12
190	13.86	13.81	11.30	11.24	0.1

Table 5. Moisture percentage of jackfruit powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	6.16	6.16	6.16	6.16	..
50	7.32	7.25	6.87	6.83	0.12
70	8.71	8.8	7.58	7.47	0.3
90	9.93	9.83	8.19	8.09	0.1
110	10.65	10.52	8.8	8.7	0.07
130	11.77	11.69	9.75	9.66	0.24
150	12.42	12.39	10.53	10.51	0.12
170	13.11	13.01	10.97	10.85	0.1
190	13.97	13.8	11.45	11.39	0.1

Fig. 2 - MOISTURE PERCENTAGE OF MANGO POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD

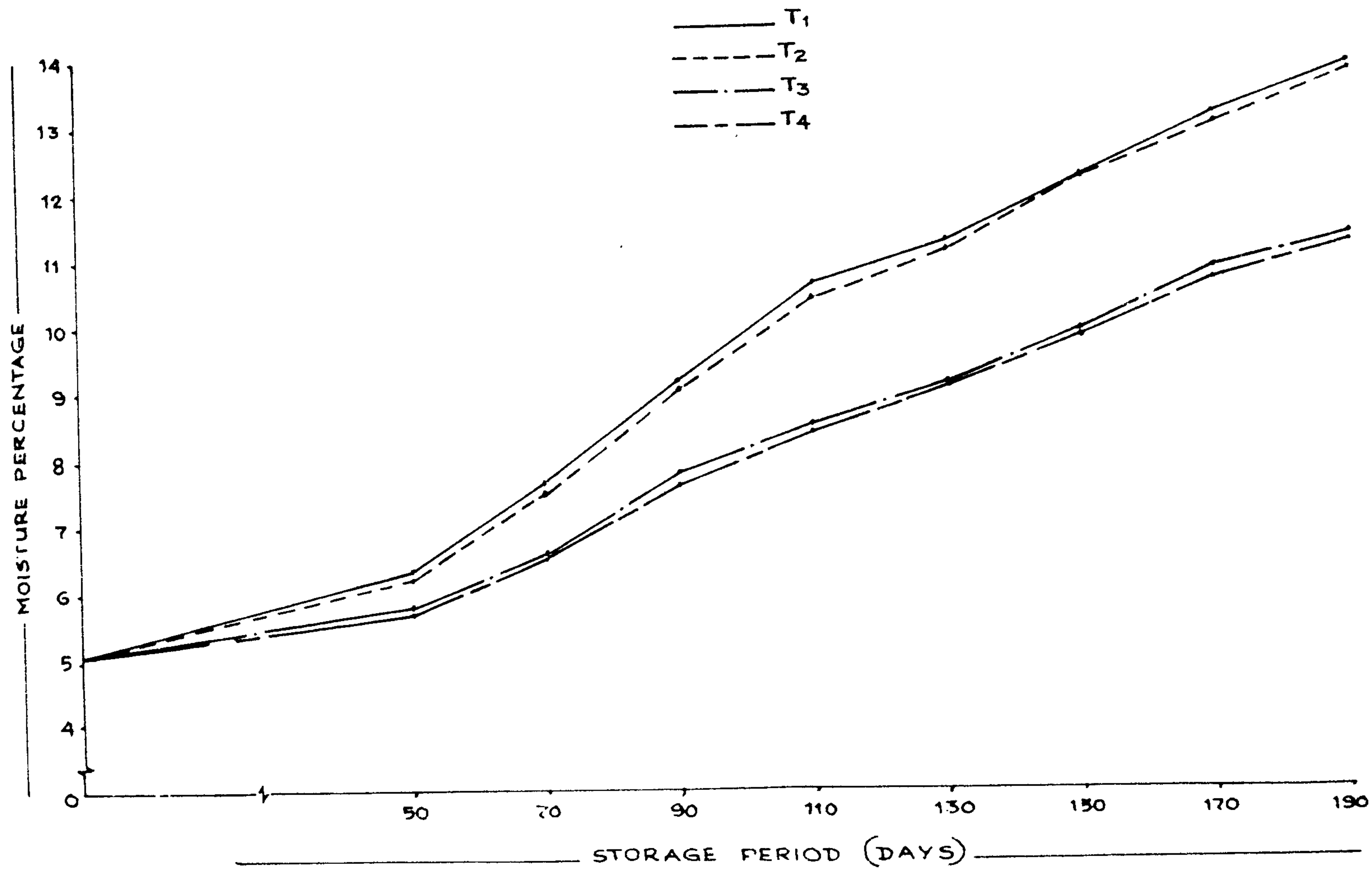
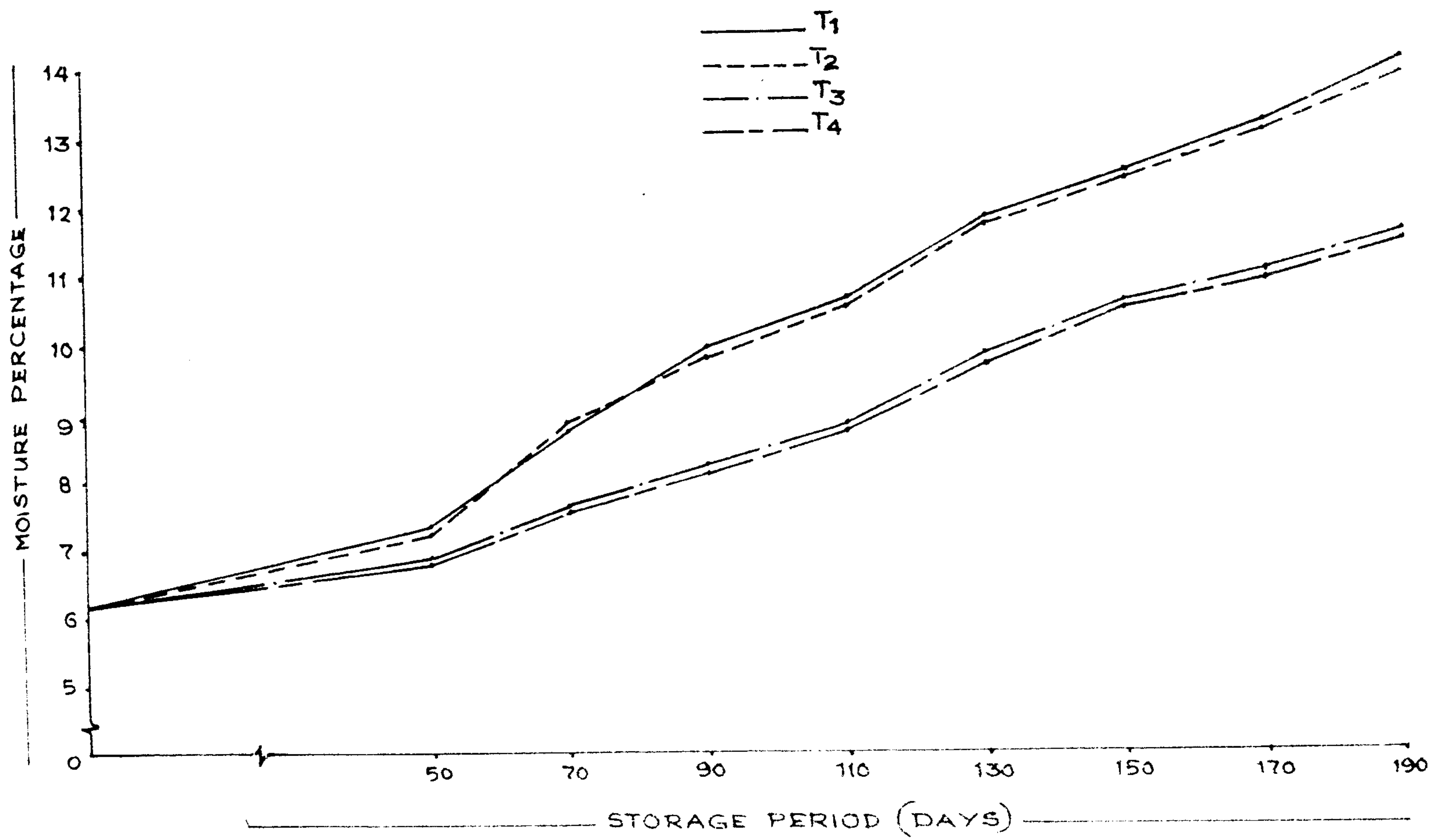


Fig. 3 - MOISTURE PERCENTAGE OF JACK FRUIT POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD.



duration of storage and after 190 days of storage T_1 recorded 13.97%, 13.8% in T_2, 11.45% in T_3 and 11.39% in T_4. T_1 and T_2 showed statistically significant difference when compared in the T_3 and T_4. During the course of storage there were slight differences with regards to the general trend.

3.2.2. Total soluble solids (T.S.S.)

3.2.2.a. Banana: Data presented in Table 6 indicate the percentage of total soluble solids (T.S.S.) in the fruit materials at different periods of storage. The ANOVA is given in Appendix III and in Fig.4. The zero storage T.S.S. content of the material was 34.9%. The influence of different packing materials on the fruit samples which resulted in an increase in the level of T.S.S. was statistically significant. After 190 days of storage, T_1 recorded the maximum of 39%, followed by T_2 (38.75%), T_3 (37.5%) and T_4 (37.4%). T_1 and T_2 were significantly different from T_3 and T_4. The minimum change in T.S.S. content was observed in T_4. This trend was true during all stages of analysis. However, there was no significant difference between the treatments at the first stage i.e., after 50 days of storage.

3.2.2.b. Mango: The T.S.S. content in fruit material under different treatments and at different periods of storage are presented in Table 7. The data have been depicted graphically in Figure 5 and its ANOVA is presented in Appendix III.

Table 6. T.S.S. percentage of banana powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	34.9	34.9	34.9	34.9	..
50	35.5	35.5	35	34.75	..
70	36.03	36	35.35	35.25	0.45
90	36.5	36.48	35.9	35.75	0.48
110	37.00	36.95	36.25	36	0.37
130	37.3	37.25	36.55	36.4	0.37
150	37.75	37.65	36.9	36.75	0.37
170	38.4	38.2	37.2	37.1	0.31
190	39	38.75	37.5	37.4	0.37

Table 7. T.S.S. percentage of mango powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	28.50	28.50	28.50	28.50	..
50	30.00	29.75	28.75	28.65	..
70	31.50	31.25	30.25	29.25	..
90	32.00	32.00	31.00	30.50	..
110	32.50	32.50	31.30	30.95	..
130	33.00	32.75	32.00	31.25	..
150	33.45	33.10	32.40	31.75	0.57
170	33.90	33.60	32.85	32.43	0.30
190	34.20	34.00	33.25	33.00	0.43

Fig. 4 - T.S.S PERCENTAGE OF BANANA POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD

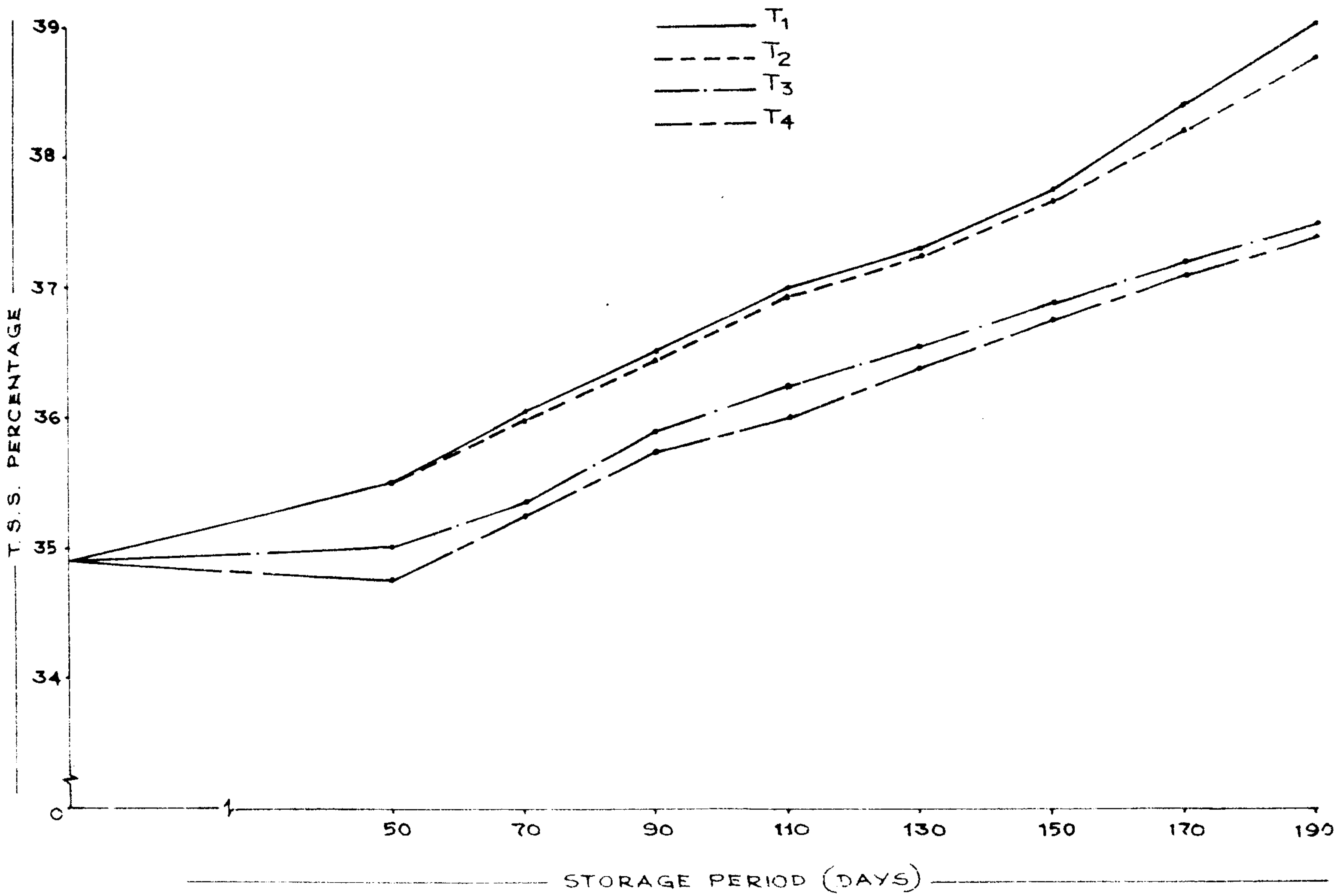
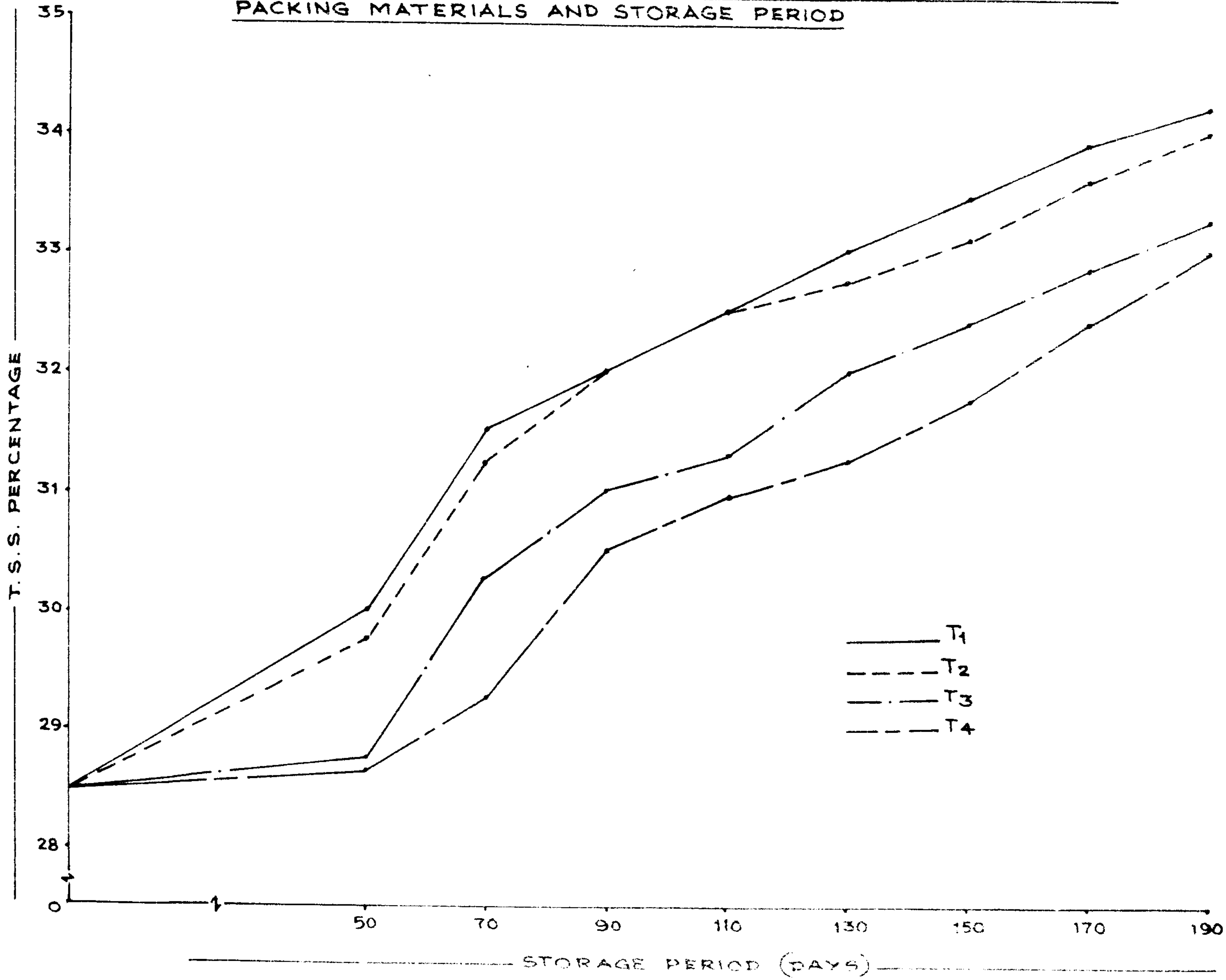


Fig. 5 - T.S.S. PERCENTAGE OF MANGO POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD



The inference drawn from the data showed that the mean T.S.S. content increased gradually in all the treatments and rate of increase was maximum in T_1 in which 34.2% T.S.S. was recorded after 190 days of storage as compared to 28.5% in zero storage. The rate of increase was minimum in T_4 with 33% T.S.S. at the final analysis. T_2 was on par with T_1 and T_3 with T_4. The differences among the treatments were not statistically significant till the period of storage crossed 150 days but thereafter the trend was similar to that observed at the final stage.

3.2.2.c. Jackfruit: The content of total soluble solids in the dehydrated jackfruit, stored at different periods of storage is presented in Table 8 and Fig.6. Appendix III gives the ANOVA. From the initial level of 47%, T.S.S. content increased to 49.76% in T_1, 49.72% in T_2, 48.99% in T_3 and 48.95% in T_4. T_3 and T_4 which were included in one group while T_1 and T_2 fell in the other and differences among them being significant. The same trend was maintained all along the course of storage.

3.2.3. Total sugars

3.2.3.a. Banana: The influence of different packing materials on the total sugar content in the fruit sample was analysed based on the data presented in Table 9 (Figure 7, Appendix IV). The initial sugar content of the

Table 8. T.S.S. percentage of jackfruit powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	47.00	47.00	47.00	47.00	..
50	47.75	47.50	47.30	47.30	0.37
70	48.00	47.98	47.50	47.45	0.30
90	48.30	48.29	47.85	47.82	0.22
110	48.65	48.64	47.99	47.96	0.30
130	49.01	48.98	48.20	48.19	0.37
150	49.25	49.20	48.40	48.37	0.37
170	49.45	49.42	48.75	48.72	0.19
190	49.76	49.72	48.99	48.95	0.30

Table 9. Total sugar percentage of banana powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	17.90	17.90	17.90	17.90	..
50	19.30	19.20	18.90	18.87	0.37
70	20.20	20.18	19.70	19.65	0.22
90	21.10	21.00	20.70	20.55	..
110	21.95	21.90	21.70	21.60	0.22
130	23.00	22.85	22.50	22.35	0.30
150	23.60	23.50	23.40	23.35	0.22
170	24.62	24.45	24.00	24.00	0.14
190	25.38	25.29	24.21	24.15	0.06

Fig. 6 - T. S. S. PERCENTAGE OF JACK FRUIT POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD

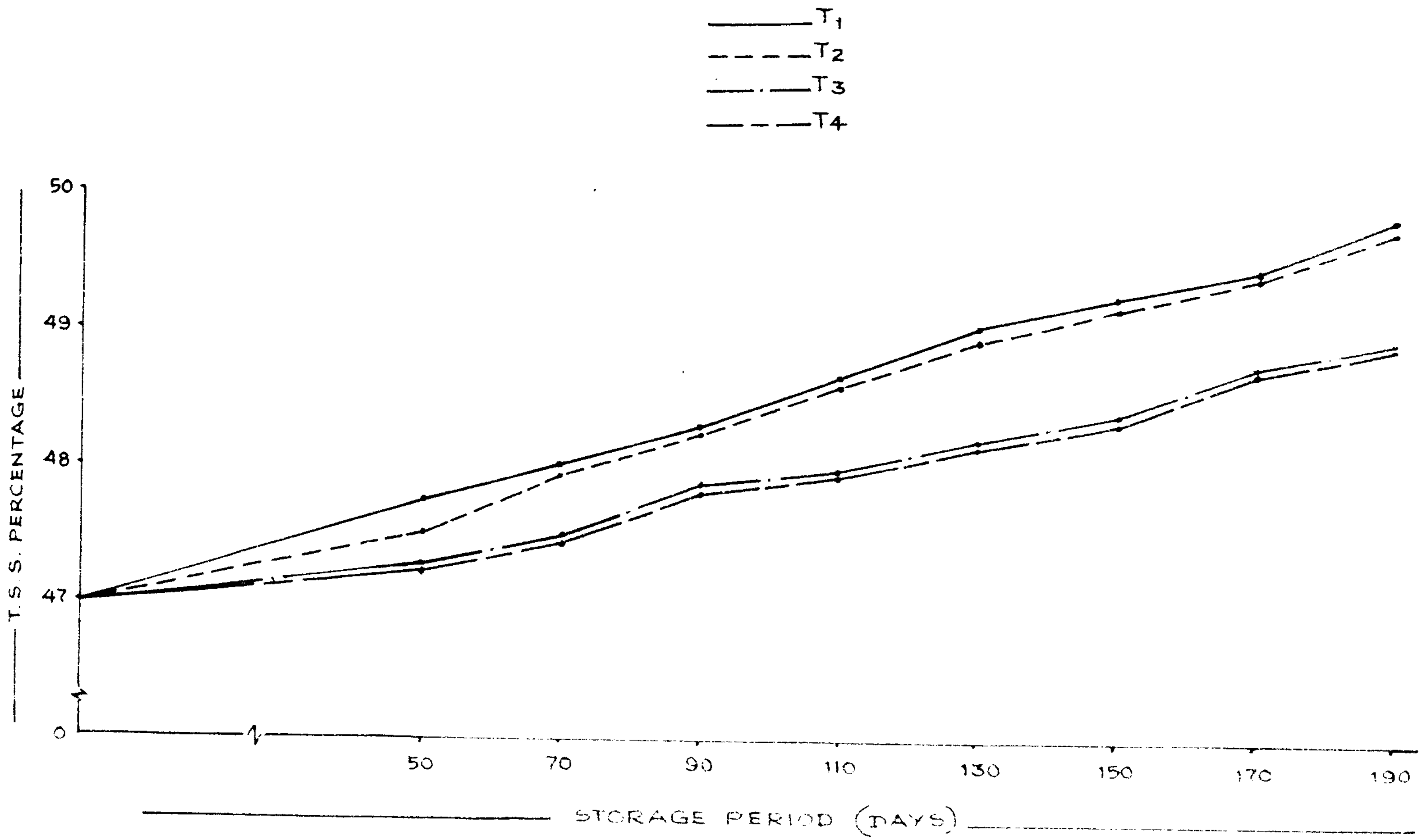
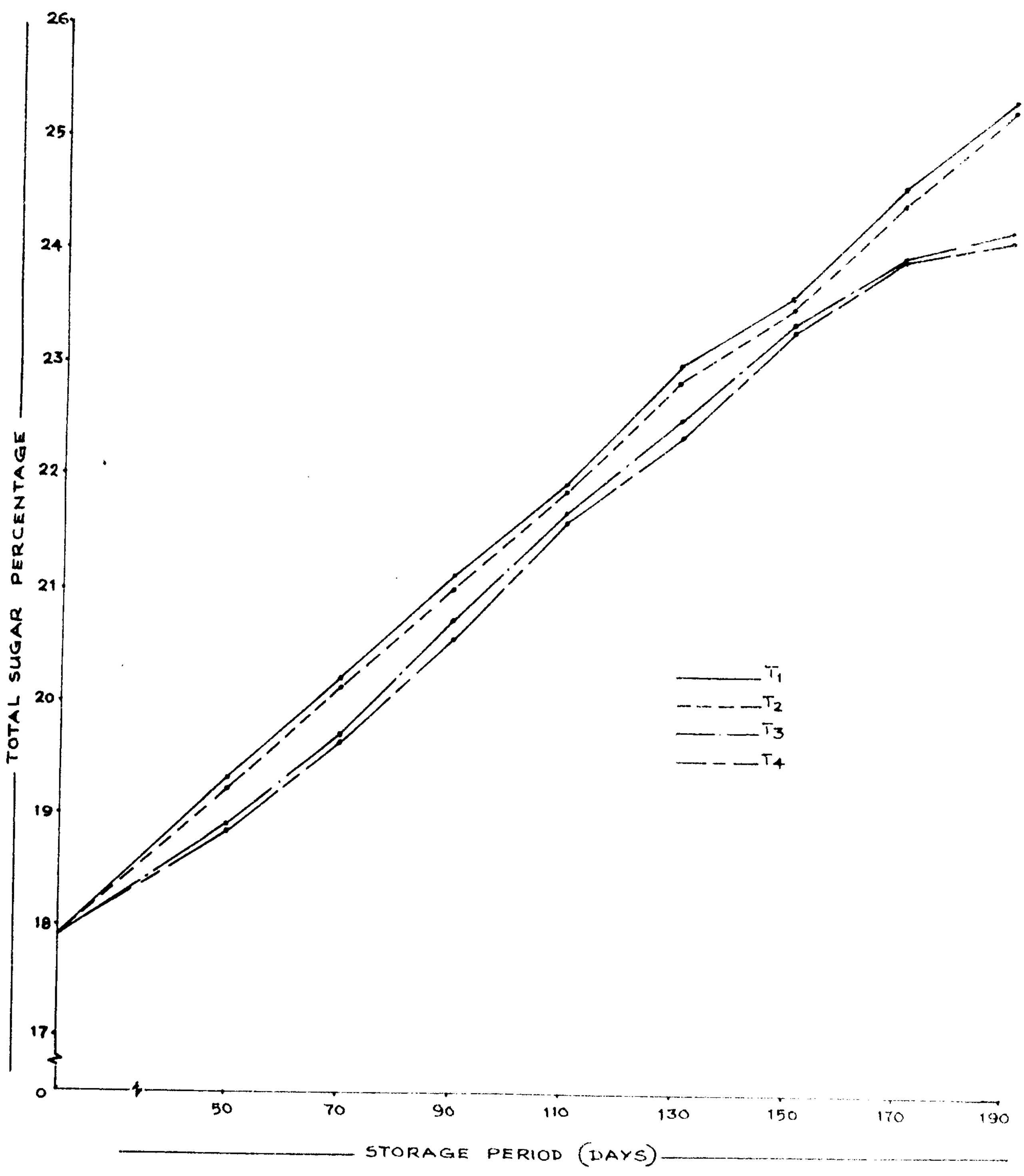


Fig. 7- TOTAL SUGAR PERCENTAGE OF BANANA POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD



fruit samples in all the treatments was 17.49%. A progressive increase was observed, as the period of storage advanced and after 190 days of storage T_1 recorded the highest value of 25.38%, followed by T_2, T_3 and T_4 with 25.29, 24.21 and 24.15% total sugars respectively. Thus, T_1 showed maximum change which was statistically significant from all other treatments with T_4 indicating the minimum change. T_2 was significantly different from T_3 as well as T_1. This trend was maintained in all the treatments during storage, although no statistical significance was observed between them after 90 days of storage.

3.2.3.b. Mango: The variations observed in the total sugar content of the fruit samples stored in the different packed materials are presented in Table 10 and Fig. 8. Appendix IV gives the ANOVA. There was a progressive increase in total sugar content in all the treatments as the duration of the storage increased. T_4 and T_3 were superior, indicating a minimum change in total sugar content (23.15 and 23.17% respectively). T_1 showed the maximum change (24.2%) followed by T_2 (23.79%) and the differences were significant. The analysis also indicated varying trends among treatments at different period of storage as evident from the Table 10.

3.2.3.c. Jackfruit: Table 11, Fig.8 and its ANOVA in Appendix IV show the changes observed in the total sugar content in the fruit samples stored at different periods. In

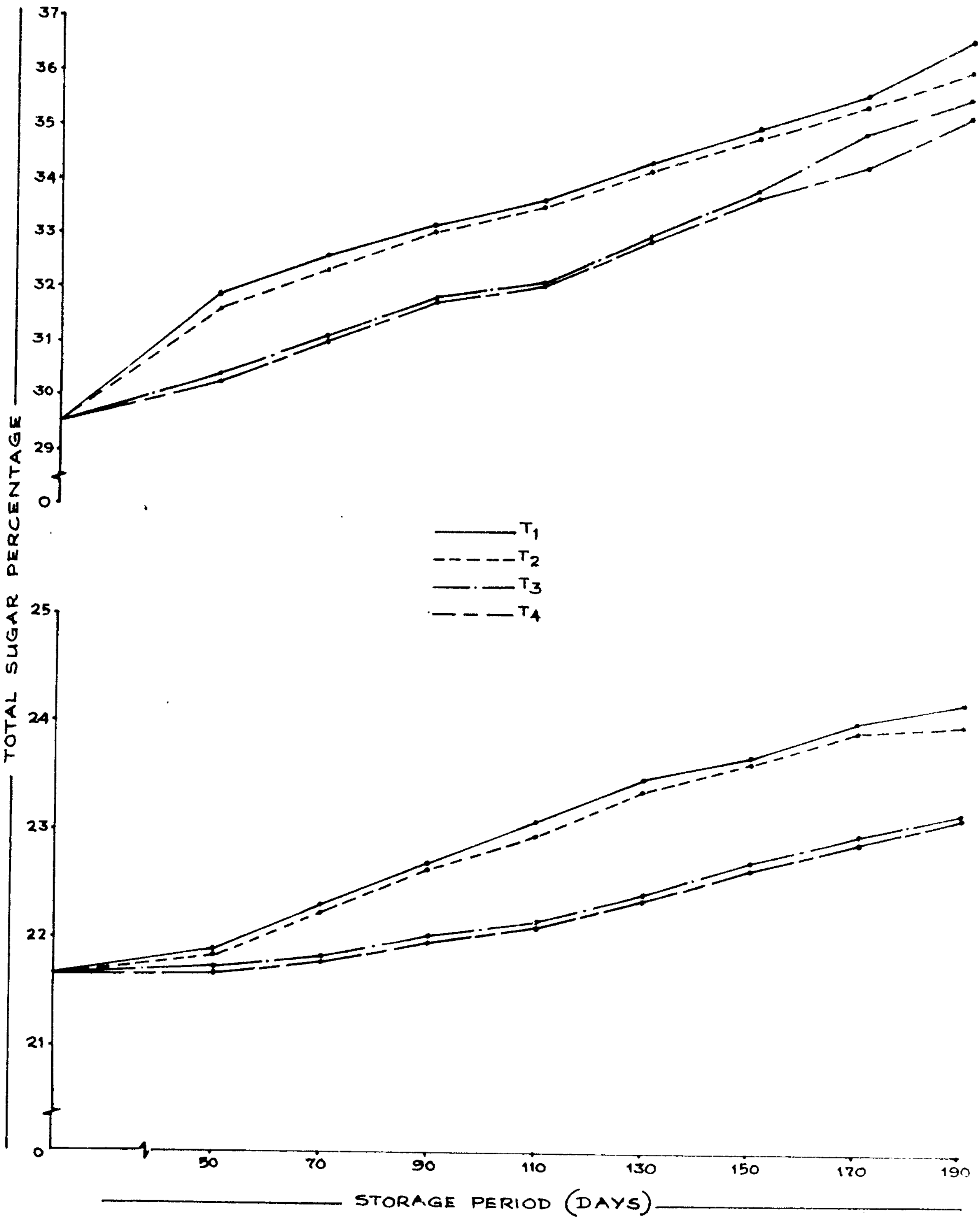
Table 10. Total sugar percentage of mango powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	21.65	21.65	21.65	21.65	..
50	21.90	21.89	21.73	21.70	0.19
70	22.31	22.29	21.85	21.83	0.06
90	22.70	22.67	22.01	21.97	0.15
110	23.10	22.97	22.19	22.16	0.19
130	23.48	23.39	22.42	22.40	0.06
150	23.67	23.65	22.70	22.66	0.17
170	24.00	23.94	22.95	22.91	0.20
190	24.20	23.97	23.17	23.15	0.11

Table 11. Total sugar percentage of jackfruit powder as influenced by the packing materials and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05 %)
0	29.50	29.50	29.50	29.50	..
50	31.89	31.56	30.36	30.27	1.14
70	32.56	32.35	31.05	31.00	0.17
90	33.15	33.05	31.80	31.74	0.15
110	33.67	33.60	32.26	32.20	0.18
130	34.35	34.29	33.00	32.98	0.10
150	35.00	34.80	33.34	33.70	0.91
170	35.64	35.47	34.92	34.26	0.30
190	36.66	36.03	35.63	35.22	1.10

Fig. 8 - TOTAL SUGAR PERCENTAGE OF JACK FRUIT AND MANGO POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD.



all the cases there was an increase in the total sugar content while the rate of increase varied between the treatments. From the initial value of 29.5%, it reached upto 36.6% in T_1, 36.03% in T_2, 35.63% in T_3 and 35.22% in T_4. Here also, T_3 and T_4 were ranked best showing minimum change in this character.

3.2.4. Reducing Sugars

3.2.4.a. Banana: The reducing sugar percentage of the fruit averaged over four replications during different periods of storage are presented in Table 12 and Fig.9. The Appendix V shows the ANOVA. A minimum change was recorded in T_4 wherein the percentage of reducing sugars increased from 14.7% to 18% during storage. The initial reducing sugar content being the same in all treatments, the maximum change being recorded in T_1 (19.08%). T_2 was on par with T_1 and T_3 on par with T_4. The difference between these two groups was statistically significant and the trend was maintained all through the storage.

3.2.4.b. Mango: Table 13 and Fig.9 showed the changes in the content of reducing sugar in the fruit samples under different treatments with storage. Appendix V shows its ANOVA. A gradual increase was noticed in all the treatments and the rate of increase was maximum in T_1 in which it increased from 12% to 16.15% and it was minimum in T_4 in which a final sugar

Table 12. Reducing sugar percentage of banana powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	14.40	14.40	14.40	14.40	..
50	15.30	15.30	15.04	15.00	0.19
70	15.80	15.79	15.40	15.37	0.26
90	16.30	16.20	15.85	15.80	0.37
110	16.75	16.70	16.25	16.22	0.30
130	17.65	17.55	16.75	16.70	0.30
150	18.00	17.90	17.25	17.19	0.30
170	18.52	18.40	17.57	17.55	0.22
190	19.08	19.00	18.01	18.00	0.22

Table 13. Reducing sugar percentage of mango powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05)
0	12.00	12.00	12.00	12.00	..
50	13.39	13.23	12.30	12.25	0.43
70	13.50	13.39	12.44	12.40	0.19
90	13.99	13.76	13.02	13.00	0.57
110	14.25	14.00	13.46	13.42	0.30
130	14.82	14.75	13.85	13.80	0.19
150	15.20	15.17	14.15	14.12	0.30
170	15.70	15.60	14.75	14.69	0.30
190	16.15	16.00	15.15	15.10	0.22

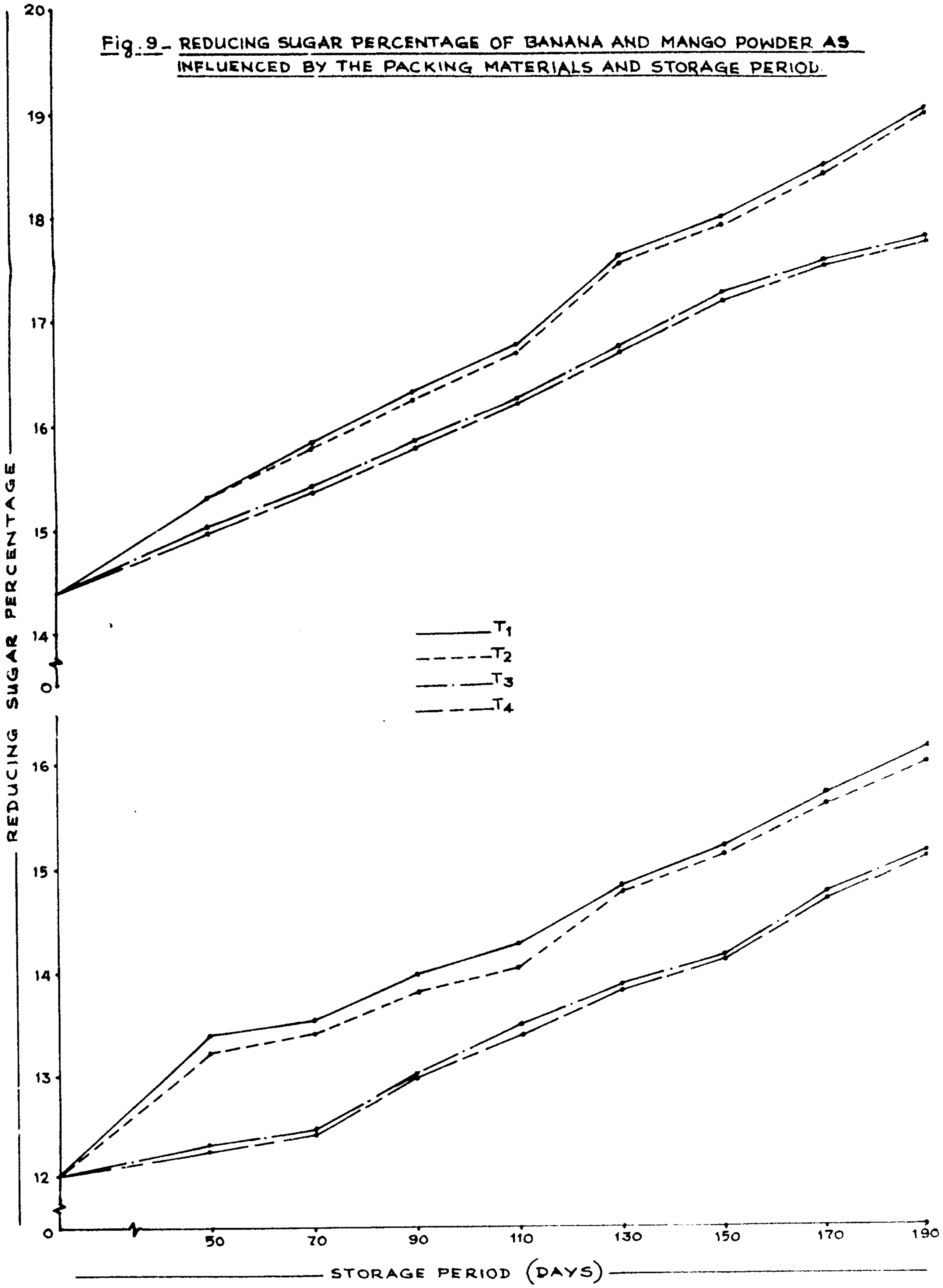


Fig. 9 - REDUCING SUGAR PERCENTAGE OF BANANA AND MANGO POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD
REDUCING SUGAR PERCENTAGE
STORAGE PERIOD (DAYS)
T1
T2
T3
T4
20
19
18
17
16
15
14
0
16
15
14
13
12
0
50
70
90
110
130
150
170
190

content of 15.15% was recorded after 190 days of storage. Difference between T_3 and T_4 and that between T_1 and T_2 was not significant. Similar trend was maintained throughout the period of storage.

3.2.4.c. Jackfruit: Changes in the reducing sugar content in the Jackfruit sample from zero storage level of 16.4% is given in Table 14, Fig.10 and its ANOVA in Appendix V. Significant difference was noticed between packing materials although there was increase in the content of reducing sugars in all the cases. Based on the analysis T_4 and T_3 were grouped together showing minimum change (22.3% and 22.45%) after 190 days of storage. T_1 and T_2 were grouped together showing maximum change (24.84 and 24.79%). The difference between these groups was significant.

3.2.5. Acidity

3.2.5.a. Banana: The titrable acidity of the fruit sample recorded during different stages of storage under different treatments are presented in Table 15 and Fig.11 with its ANOVA in Appendix VI. In zero storage an acidity of 2.05% was observed in all the treatments. And during the course of storage there was a gradual decrease in acidity. As evident from the table, after 190 days of storage T_1 showed lowest titrable acidity of 1.48% and T_4 recorded highest value 1.55%. The differences between T_2 and T_3, T_1 and T_3 and T_1 and T_4 were significant. Analysis at different

Table 14. Reducing sugar percentage of jackfruit powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	16.45	16.45	16.45	16.45	..
50	18.54	17.99	17.49	17.25	1.06
70	19.40	18.54	17.98	17.37	1.22
90	21.22	20.77	18.95	18.53	1.41
110	22.77	22.34	20.37	20.17	1.90
130	23.21	23.10	21.00	20.79	0.43
150	23.99	23.80	21.77	21.41	0.17
170	24.32	24.15	22.10	21.99	0.15
190	24.84	24.79	22.45	22.30	0.15

Table 15. Acidity percentage of banana powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value (0.05%)
0	2.05	2.05	2.05	2.05	..
50	1.96	1.97	2.00	2.01	0.03
70	1.88	1.90	1.92	1.93	0.04
90	1.80	1.82	1.84	1.85	0.04
110	1.71	1.73	1.75	1.76	0.04
130	1.64	1.66	1.68	1.70	0.03
150	1.59	1.62	1.64	1.65	0.04
170	1.55	1.58	1.61	1.63	0.03
190	1.48	1.50	1.54	1.55	0.03

intervals indicated that a similar trend was maintained during the course of storage.

3.2.5.b. <u>Mango:</u> Changes in titratable acidity of the fruit sample under different treatments are presented in Table 16, Fig.11 and ANOVA in Appendix VI. From the zero storage of 3.77, the titrable acidity decreased with storage in all cases. After 190 days of storage a mean acidity of 3.2% was recorded in T_1, a maximum of 3.41% in T_4, T_2 and T_3 recorded 3.23 and 3.4% respectively and the difference among the treatments at this stage (after 190 days of storage) was not significant. But analysis at different intervals of storage indicated significant difference among the treatments at varying levels.

3.2.5.c. <u>Jackfruit:</u> Table 17, Fig.10 and its ANOVA in Appendix VI presents the changes observed in the titrable acidity in the stored fruit sample. From the initial level of 3.6% the acidity decreased in all the treatments. The maximum change was recorded in T_1 (3.01%) after 190 days of storage and minimum change was recorded in T_4 (3.22%) after 190 days of storage. Difference between T_1 and T_3, T_2 and T_3 was significant. T_3 was on par with T_4 while T_1 went on par with T_2.

4. <u>Standardisation of syrup strength for reconstitution</u>

Organoleptic qualities of reconstituted chips of banana,

Table 16. Acidity percentage of mango powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D. value (0.05%)
0	3.77	3.77	3.77	3.77	..
30	3.70	3.73	3.75	3.76	0.10
70	3.62	3.64	3.69	3.71	0.06
90	3.55	3.56	3.64	3.65	0.19
110	3.46	3.49	3.58	3.59	0.06
130	3.39	3.41	3.51	3.53	0.06
150	3.30	3.32	3.47	3.48	0.06
170	3.26	3.28	3.44	3.45	0.06
190	3.20	3.23	3.40	3.41	..

Table 17. Acidity percentage of jackfruit powder as influenced by the packing material and storage period

Storage period (days)	T_1	T_2	T_3	T_4	C.D.value
0	3.60	3.60	3.60	3.60	..
50	3.46	3.48	3.54	3.56	0.03
70	3.41	3.43	3.51	3.52	0.04
90	3.35	3.37	3.45	3.47	0.03
110	3.27	3.29	3.41	3.44	0.10
130	3.20	3.24	3.37	3.40	0.04
150	3.14	3.17	3.30	3.34	0.03
170	3.09	3.12	3.24	3.27	0.04
190	3.01	3.04	3.19	3.22	0.16

Fig. 10 - ACIDITY AND REDUCING SUGAR PERCENTAGE OF JACK FRUIT POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD.

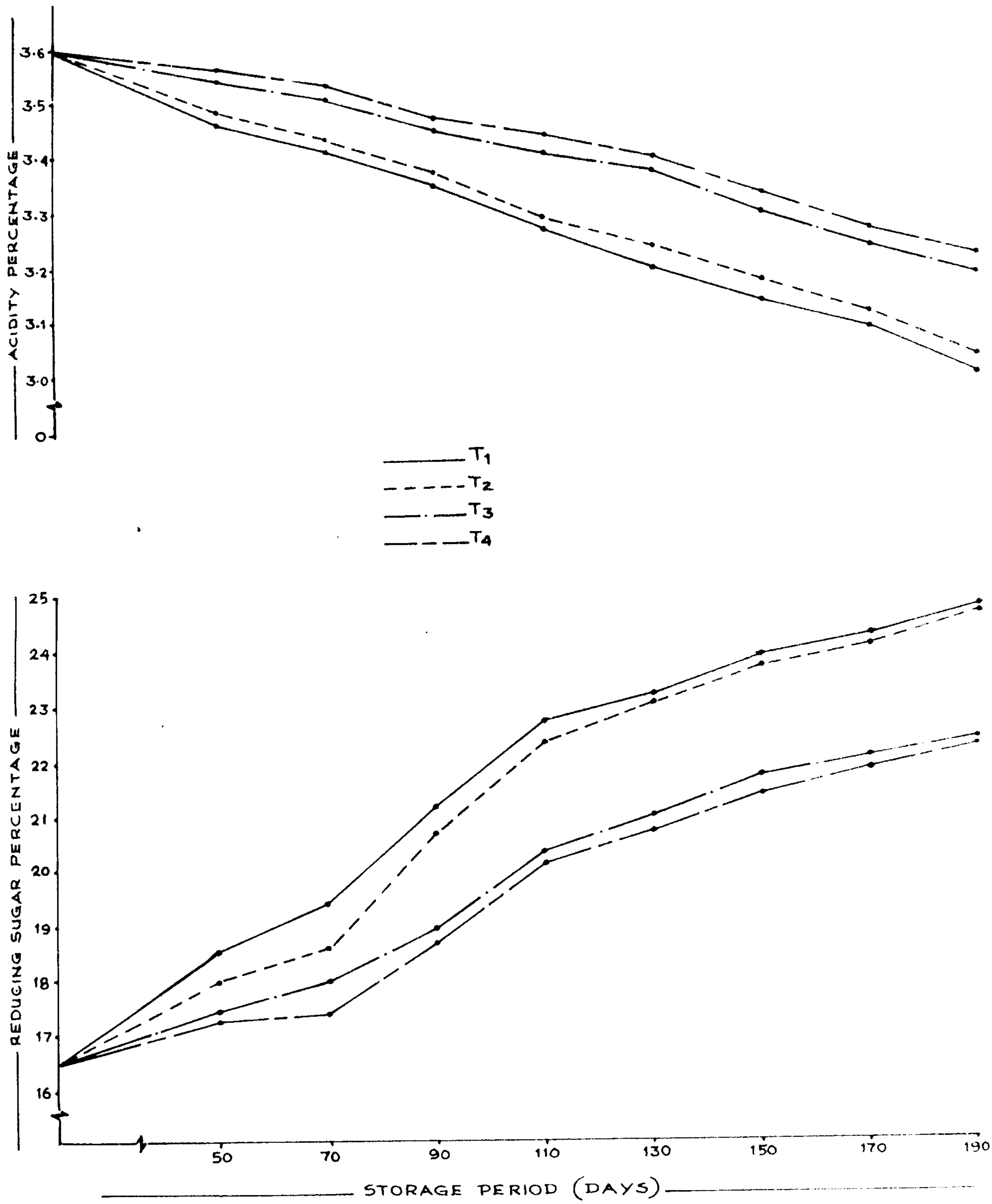
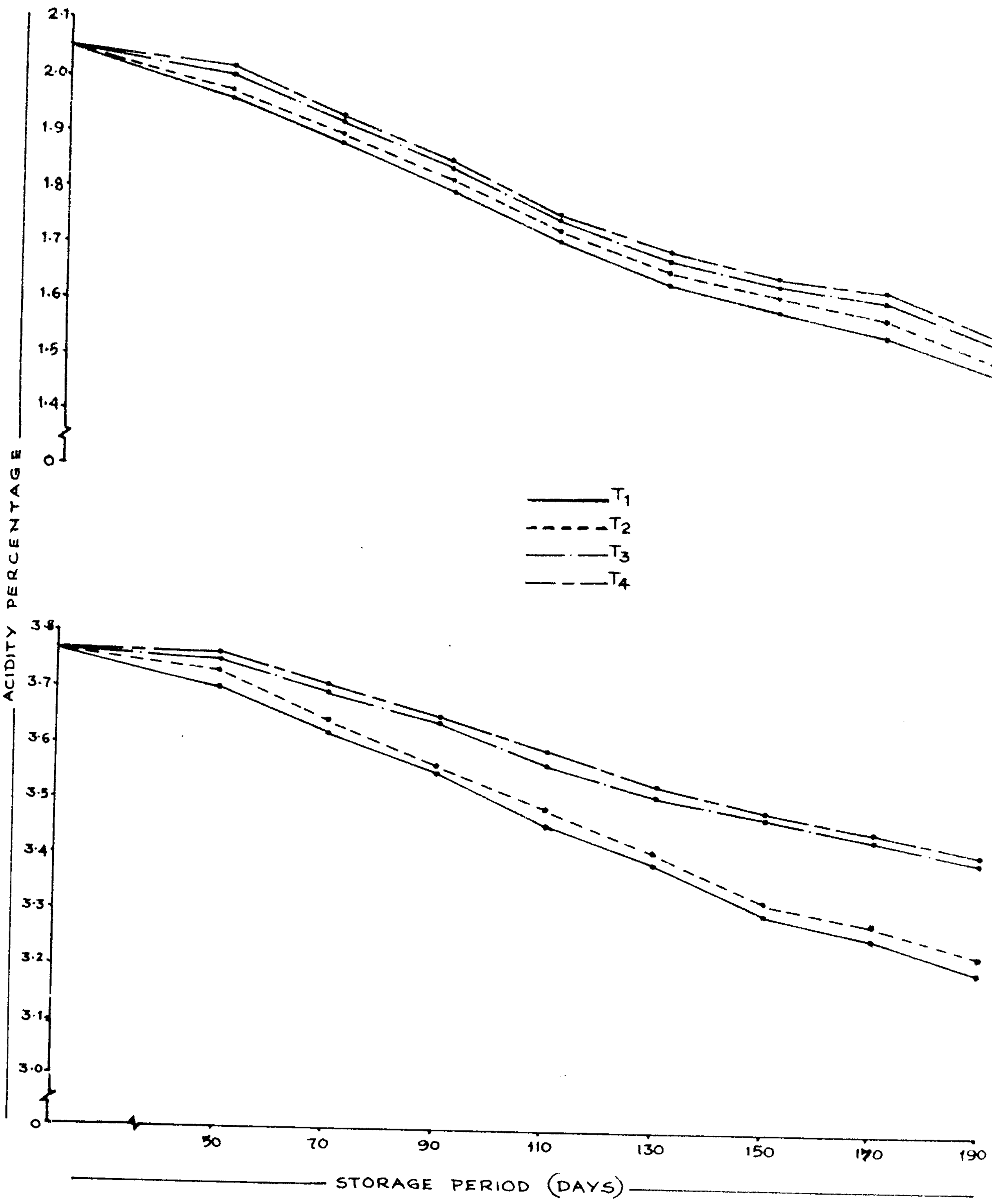


Fig. 11 - ACIDITY PERCENTAGE OF BANANA AND MANGO POWDER AS INFLUENCED BY THE PACKING MATERIALS AND STORAGE PERIOD



mango and jackfruit in solutions of different syrup strength are furnished in Table 18. It may be seen from the data that the optimum syrup strength for reconstituting the dehydrated banana and mango chips was 25% syrup whereas it was 30% syrup for the jackfruit.

5. Organoleptic qualities of reconstituted banana, mango and jackfruit

5.1. Banana

From the detailed organoleptic assessment of reconstituted banana chips presented in Table 19, it is evident that packing materials and storage period have a pronounced effect on these qualities of banana. Appearance, taste and overall rating of the material stored in craft paper bag remained good upto 70 days of storage and showed a deteriorating trend later on. By 130 days of storage the product packed in craft paper bag became unacceptable. In the case of butter paper bag, with the exception of the appearance, the product remained good for 110 days and became unacceptable after that period. In polythene packed material, retentions of organoleptic qualities was observed during storage for 110 days and was acceptable upto 170 days. A similar trend was observed with polypropylene bag.

Organoleptic qualities of the reconstituted banana powder is presented in Table 20. It is seen from the Table

Table 18. Standardisation of syrup strength for reconstitution of banana, mango and jackfruit chips

Particulars	Syrup strength	T_1	T_2	T_3	T_4
a. Banana chips					
Dried weight to reconstituted weight	-	1:3.0	1:3.0	1:3.06	1:3.06
	20	Poor	Poor	Poor	Poor
	25	Good	Good	Good	Good
	30	Fair	Fair	Fair	Fair
	35	Fair	Fair	Fair	Fair
b. Mango chips					
Dried weight to reconstituted weight	-	1:3.0	1:3.0	1:3.05	1:3.05
	20	Poor	Poor	Poor	Poor
	25	Good	Good	Good	Good
	30	Fair	Fair	Fair	Fair
	35	Fair	Fair	Fair	Fair
c. Jackfruit chips					
Dried weight to reconstituted weight	-	1:3.0	1:3.0	1:3.04	1:3.04
	20	Poor	Poor	Poor	Poor
	25	Poor	Poor	Poor	Poor
	30	Good	Good	Good	Good
	35	Fair	Fair	Fair	Fair

Table 19. Organoleptic qualities of reconstituted banana chips (in 25% syrup) as influenced by packing materials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
70	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
90	A	Fair	Fair	Good	Good
	T	Good	Good	Good	Good
	O	Fair	Good	Good	Good
110	A	Fair	Fair	Good	Good
	T	Fair	Good	Good	Good
	O	Poor	Good	Good	Good
130	A	-	Fair	Good	Good
	T	-	Fair	Fair	Fair
	O	-	Poor	Poor	Good
150	A	-	-	Good	Good
	T	-	-	Fair	Fair
	O	-	-	Good	Good
170	A	-	-	Good	Good
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair
190	A	-	-	Fair	Fair
	T	-	-	Fair	Fair
	O	-	-	Poor	Poor

A = Appearance T = Taste O = Overall rating

Table 20. Organoleptic qualities of the reconstituted banana powder for preparation of "Payasam" as influenced by the packing materials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	C	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
70	C	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
90	C	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
110	C	Good	Good	Good	Good
	T	Fair	Good	Good	Good
	O	Fair	Good	Good	Good
130	C	Good	Good	Good	Good
	T	Poor	Fair	Good	Good
	O	Poor	Fair	Good	Good
150	C	-	Good	Good	Good
	T	-	Poor	Good	Good
	O	-	Poor	Good	Good
170	C	-	-	Good	Good
	T	-	-	Good	Good
	O	-	-	Good	Good
190	C	-	-	Good	Good
	T	-	-	Good	Good
	O	-	-	Good	Good

C = Consistency
T = Taste
O = Overall rating

that the craft paper pack remained good upto 90 days and was not acceptable beyond 130 days of storage. Butter paper packed material also remained in good condition upto 110 days of storage, but was not suitable for storage beyond 150 days. T_3 and T_4 packed materials remained good after 190 days of storage.

5.2. Mango

Table 21 shows the organoleptic qualities of reconstituted mango chips as influenced by the packing materials during storage. It was observed from the table that T_3 and T_4 packed materials could be accepted upto 130 days of storage beyond which the product showed poor quality. T_1 and T_2 remained good upto 70 days of storage and quality deteriorated slowly and the product was not acceptable after 110 days in T_1 and 130 days in T_2.

Data on the reconstituted mango powder i.e., preparation of "Payasam" is detailed in Table 22. It may be seen from the Table that T_1 could be acceptable upto 170 days of storage and after 190 days of storage it was not accepted. As in the case of T_2 the product was good upto 130 days of storage but became unacceptable after 190 days of storage. T_3 and T_4 remained excellent upto 90 days of storage and remained good throughout the storage period.

Table 21. Organoleptic qualities of the reconstituted mango chips (in 2% syrup) as influenced by the packing materials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
70	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
90	A	Fair	Fair	Good	Good
	T	Fair	Good	Good	Good
	O	Fair	Fair	Good	Good
110	A	Fair	Fair	Good	Good
	T	Poor	Fair	Fair	Fair
	O	Poor	Fair	Fair	Fair
130	A	-	Fair	Good	Good
	T	-	Poor	Fair	Fair
	O	-	Poor	Fair	Fair
150	A	-	-	Fair	Fair
	T	-	-	Fair	Fair
	O	-	-	Poor	Poor
170	A	-	-	Fair	Fair
	T	-	-	Poor	Poor
	O	-	-	Poor	Poor
190	-	-	-	-	-

Table 22. Organoleptic qualities of the reconstituted mango powder for preparation of "Payasam" as influenced by the packing materials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	C	Excellent	Excellent	Excellent	Excellent
	T	Excellent	Excellent	Excellent	Excellent
	O	Excellent	Excellent	Excellent	Excellent
70	C	Good	Good	Excellent	Excellent
	T	Good	Excellent	Excellent	Excellent
	O	Good	Good	Excellent	Excellent
90	C	Good	Good	Good	Good
	T	Good	Good	Excellent	Excellent
	O	Good	Good	Excellent	Excellent
110	C	Good	Good	Good	Good
	T	Good	Good	Excellent	Excellent
	O	Good	Good	Good	Good
130	C	Good	Good	Good	Good
	T	Fair	Good	Good	Good
	O	Good	Good	Good	Good
150	C	Good	Good	Good	Good
	T	Fair	Fair	Good	Good
	O	Fair	Fair	Good	Good
170	C	Good	Good	Good	Good
	T	Fair	Fair	Good	Good
	O	Fair	Fair	Good	Good
190	C	Fair	Fair	Good	Good
	T	Poor	Fair	Good	Good
	O	Poor	Poor	Good	Good

5.3. Jackfruit

Table 23 presents the organoleptic qualities of jackfruit reconstituted chips as influenced by the packing materials and storage period. It is evident from the table that T_1 was good upto 90 days of storage and was not acceptable beyond 130 days of storage. T_2 remained good upto 90 days of storage and became unacceptable beyond 150 days of storage. T_3 and T_4 remained good upto 150 days of storage and remained acceptable upto 190 days of storage.

Organoleptic qualities of the reconstituted jackfruit powder is presented in Table 24. This table showed that T_1 and T_2 were good upto 70 days of storage, but could not be accepted after 110 days in T_1 and 130 days in T_2. T_3 and T_4 showed good results upto 130 days of storage and remained acceptable upto 190 days of storage.

6. Pest and diseases

While storing the dehydrated banana, mango and jackfruit chips as well as powder materials, there was no incidence of pest and diseases in the product.

Table 23. Organoleptic qualities of the reconstituted jackfruit chips (in 30% syrup) as influenced by the packing paterials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
70	A	Good	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
90	A	Fair	Good	Good	Good
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
110	A	Fair	Good	Good	Good
	T	Fair	Fair	Good	Good
	O	Fair	Fair	Good	Good
130	A	Fair	Fair	Good	Good
	T	Poor	Fair	Good	Good
	O	Poor	Fair	Good	Good
150	A	-	Fair	Good	Good
	T	-	Poor	Good	Good
	O	-	Poor	Good	Good
170	A	-	-	Good	Good
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair
190	A	-	-	Good	Good
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair

Table 24. Organoleptic qualities of the reconstituted jackfruit powder for preparation of "Payasam" as influenced by the packing materials and storage period

Storage period (days)	Characters	T_1	T_2	T_3	T_4
50	C	Fair	Fair	Fair	Fair
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
70	C	Fair	Fair	Fair	Fair
	T	Good	Good	Good	Good
	O	Good	Good	Good	Good
90	C	Fair	Fair	Fair	Fair
	T	Fair	Good	Good	Good
	O	Fair	Good	Good	Good
110	C	Fair	Fair	Fair	Fair
	T	Poor	Fair	Good	Good
	O	Poor	Fair	Good	Good
130	C	-	Fair	Fair	Fair
	T	-	Poor	Good	Good
	O	-	Poor	Good	Good
150	C	-	-	Fair	Fair
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair
170	C	-	-	Fair	Fair
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair
190	C	-	-	Fair	Fair
	T	-	-	Fair	Fair
	O	-	-	Fair	Fair

Discussion

DISCUSSION

Moisture and water activity had been long recognised as important factors leading to the perishability of fruits and vegetables. Successful removal of moisture to safer limits without hindering the original properties was, once a long cherished dream of food technologists. The advent of solar energy as a means for reducing the water activity was the first success in this respect. However, serious considerations on the hygine of the finished product, economy of the floor space for drying and in short the convenience was achieved by the innovation of dehydration.

The quality of the dehydrated materials should be well comparable with, or nearest to the maximum with the natural properties of raw materials employed. The dehydration procedure, drying rate and heat transfer characteristics are recognised to be the factors of prime concerned in this respect. Recently the role of packaging on the quality of the dehydrated materials during storage has attracted considerable attention. Permeability to light, moisture and moisture absorption characteristics were the relevant points to be considered while selecting the packaging for dehydrated materials. Retention of the physical-chemical characteristics of the dehydrated materials during storage is dependent on the material used for packing. The relevant findings of the present investigation are discussed in the following section:

Suitable varieties of banana, mango and jackfruit were selected for the studies. The physical-chemical composition of the selected fruits revealed their suitability for dehydration. However, the moisture rich nature of these fruits indicated their perishability and post-harvest storage problems. These observations pointed out the need for moisture reduction for extending the storage life.

1. <u>Pre-drying treatments of the fruits</u>

Certain treatments are given before the fruits are subjected to drying. The results of these treatments showed that the dipping of the fruits in KMS solution as a pre-drying treatment increases the fruit weight. The maximum increase in weight was recorded in banana, followed by jack and mango. A negative relationship was noticed between the moisture content of the fruit and the increase in weight following the dip in the KMS solution. This may be related to the osmotic flow of moisture to the point of equilibrium. Higher osmotic gradient results in higher moisture flow. So, fruits with low moisture (in case of banana 70%) content is expected to pick up more moisture in the dipped solution as compared with fruits rich in moisture (in case of mango 85%). The increased weight of the dip treatment is solely attributed to the impregnation of water with the dissolved KMS.

2. Drying of the fruits

2.1. Sun-drying

The material dried under the sun remained moist and pulpy even after 25 days of drying indicated the poor moisture-transfer ratio during sun drying under Vellanikkara condition. Accordingly the poor efficiency of sun drying observed in the present investigation appeared to be related to the higher relative humidity in the atmosphere. In spite of having an approximate maximum temperature of $34 \pm 1^{o}C$, a minimum temperature of $25 \pm 1^{o}C$ and reasonably good sunshine hours, the poor drying rate and efficiency were recorded. Adequate measures also were taken to avoid the direct deleterious effects of the rainfall.

The moisture transfer during drying is directly related to the vapour pressure gradient. This may be achieved by providing an increased difference in the relative humidity (R.H.) of the fruits and the surrounding atmosphere. Lower the vapour pressure in the surrounding atmosphere will result in the moisture drive from the fruit outwardly. The relative humidity data presented in appendix I shows that the fruit and surrounding atmosphere is almost in equilibrium relative humidity (E.R.H.). The poor efficiency of sun drying is thus related to the E.R.H. condition existed during sun-drying.

2.2. Mechanical drying

It was observed that the drying time was directly related to the fruit weight observed after dipping treatment but not with the initial moisture content. Thus it appears that during the dipping process the increase in fruit weight was mostly due to moisture absorption and the drying time is directly related to the moisture content of the fruit at the time of drying. Drying ratio was found to be closely related to the initial moisture content of the fruit but not with moisture obtained during the dip treatment. This observation may be justified from the fact that the drying ratio is strictly and directly a function of the total solids.

2.3. Browning during drying

Browning of the product was observed during dehydration after 48 hours of drying. This browning reactions may be attributed to enzymetic or non-enzymetic. A final judgement in this connection will await further investigation. However, survival of enzymes at temperature employed (65 ± 5°C) in dehydration appeared to be difficult. The possibility of enzyme browning during dehydration was not likely. The sugar rich nature of all the three fruits under study points out the possibility of non-enzymetic browning possibly by the caramelisation type.

3. Storage studies

3.1. Effect of storage conditions on the quality of dehydrated banana, jack and mango during storage

The effect of atmosphere under which the dehydrated materials are stored was found to detect the quality of the material during storage. The occurrence of fermentation in the dehydrated materials stored in open condition by the 50th day of the storage may be due to the hygroscopic moisture picked up of the dehydrated materials leading to favourable conditions for fermentation breakdown. The absence of such defects in material stored inside the steel trunk even at the end of 190 days of storage also provided positive proof in this respect.

3.2. Effect of packing materials in the chemical composition of dehydrated materials during storage

3.2.1. Moisture

In case of banana the initial moisture content i.e., at zero storage was 4.14%. The moisture content after 190 days of storage was recorded as 13.2% in T_1 (craft paper bag), 13.16% in T_2 (butter paper bag), 10.18% in T_3 (polythene bag) and 10.17% in T_4 (polypropylene bag). The minimum change in moisture content among different packing materials tried in the experiment was T_4 and T_3. The maximum change in moisture content was in T_1 (13.2%). From the data on the moisture content of the different packing materials during storage showed that dehydrated banana picked up considerable moisture indicating its hygroscopic nature.

As in the case of mango the rate of absorption of moisture was highest in T_1 in which 13.86% moisture was recorded after 190 days of storage. The minimum change was found in T_4 in which it was 11.24% after 190 days of storage.

Similarly in the case of jackfruit T_1 showed a maximum change during storage i.e. (13.97%) after 190 days of storage, T_4 and T_3 had the minimum changes in moisture content i.e. (11.39 and 11.45% respectively). In all these three fruits T_4 and T_3 showed the minimum changes in moisture content during storage.

The rapid increase in moisture content of the sample after 190 days of storage in all the packing materials, which may be attributed to the high humidity in the atmosphere. The gain in moisture from the samples was mainly due to water vapour transmission property of the bags. Gain in moisture was more in paper bags than polypropylene and polythene bags which may be because of the more permeability to moisture of the paper bags as compared to polypropylene and polythene bags. So the varying performance of the packing materials may be due to their varying permeability to moisture. Accordingly, it appeared that T_4 and T_3 may be recommended for storing dehydrated banana, mango and jackfruit without much moisture pick up and quality deterioration in this respect. This finding is in agreement with Bhatia and Amin (1962), Mahadeviah (1977), Balasubramanyam and Anandaswamy (1979) and Hohn(1981).

3.2.2. Total soluble solids (T.S.S.)

From the data presented in Table 6, it is seen that the T.S.S. of banana was influenced by different packing materials on the fruit samples which resulted an increase in the level of T.S.S. T_1 recorded a maximum of 39% T.S.S. after 190 days of storage. The minimum change in T.S.S. content was observed in T_4 (37.4%) followed by T_3 (37.5%).

In mango, T.S.S. content increased gradually in all the treatments and rate of increase was maximum in T_1 in which 34.2% T.S.S. was recorded after 190 days of storage as compared to 28.5% in zero storage. T_4 showed a minimum change of T.S.S. (33%).

Similarly, in jackfruit, data showed that from the initial level of 47%, T.S.S. content increased to 49.76% in T_1, 49.72% in T_2, 48.99% in T_3 and 48.95% in T_4. Thus T_4 and T_3 showed the minimum change in T.S.S. content while T_1 and T_2 showed maximum change.

Thus T.S.S. variation appeared to be related to moisture pick up. Hydrolytic inversion of starch to constituents like soluble solid which might have been enhanced due to moisture pick up and storage period also might have contributed to the increase in T.S.S. recorded by T_1. The minimum T.S.S. was recorded by T_4 and T_3 in all the three fruits might be due to the minimum occurrence of these factors. Accordingly T_4 and T_3 was found to be suitable for packing of dehydrated banana, mango and jackfruit.

3.2.3. <u>Total sugars</u>

Data in Table 9 shows that initial sugar content of banana sample in all the treatments was 17.49%. After 190 days of storage T_1 recorded the highest value of 25.38%, followed by T_2, T_3 and T_4 with 25.29, 24.21 and 24.15% of total sugar, respectively. T_1 showed a maximum change which was statistically significant from all other treatments. T_4 showed a minimum change. T_3 was significantly different from T_2 and T_1. From the data in Table 10 it was seen that there was a progressive increase in total sugar content in all the treatments as the duration of storage increased. T_4 and T_3 were superior indicating a minimum change in total sugar content (23.17 and 23.15%). T_1 showed the maximum change (24.2%) followed by T_2 (23.79%) and difference were significant.

It is also evident from the Table 11 that there was increased trend in total sugar in jackfruit, packed in different packing materials. The rate of increase in total sugar varied between all the four treatments. From the initial value of 29.5% it reached upto 36.6% in T_1, 36.03% in T_2, 35.63% in T_3 and 35.22% in T_4. Here also T_4 and T_3 showed the minimum change.

These changes in the total sugar in all these three fruits under study might be due to more rapid hydrolysis of polysacchrides and their subsequent inversion to sugars. Thompson and Schrader (1949) also had the same opinion with this finding. They observed starch content decreased throughout the storage period irrespective of the packages could be ascribed to the hydrolysis of starch. The hydrolytic changes might be enhanced by the moisture present in the fruit samples. Kikon (1975) is in agreement with this finding.

3.2.4. <u>Reducing sugars</u>

From Table 12 it was seen that the reducing sugar in banana changed during the storage in different packing materials showing an increased trend. A minimum change was recorded in T_4 wherein the percentage of reducing sugar content increased from 14.7% to 18%. A maximum change was recorded in T_1 (19.08%). T_4 and T_3 were significantly different from T_1 and T_2.

Mango powder also showed a gradual increase in all the treatments and rate was maximum in T_1 in which it increased from 12% to 16.15% and it was minimum in T_4 where a final sugar content of 15.15% was recorded after 190 days of storage. Here T_4 showed its superiority over T_1 showing a minimum change in the reducing sugar content during storage.

Changes in reducing sugar content in jackfruit sample from zero storage level of 16.4% can be seen from Table 14. Data in this table showed significant difference between the packing materials showing increasing trend in all the cases. T_4 and T_3 showed a minimum change (22.3% and 22.45%) after 190 days of storage. T_1 and T_2 showed maximum change (24.84 and 24.79% respectively). The difference between these groups were significant. Thus all the three fruits taken for the experiment showed an increasing trend of reducing sugar in all the treatments during storage. This increase in reducing sugar may be attributed to the hydrolytic changes of starch and increase in the reducing sugar. This finding is in conformity with the findings of Thompson and Schrader (1949), Kiko (1975) and Rao and Roy (1980).

3.2.5. Acidity

The titrable acidity in the dehydrated banana showed a gradual decrease during the course of storage. As evident from the Table 15 after 190 days of storage T_1 showed lowest titrable acidity of 1.48% and T_4 recorded highest value of 1.55%. The difference between all the treatments, viz., T_2 and T_3, T_1 and T_3 and T_1 and T_4 were significant.

From Table 16 it was found that in mango samples, the titrable acidity decreased with storage in all cases. After 190 days of storage an acidity of 3.2% was recorded in T_1, at a maximum of 3.41% in T_4. T_2 and T_3 recorded 3.23 and 3.4% respectively. Here T_4 showed minimum change in acidity while T_1 showed maximum change.

In jackfruit powder also changes observed in the titrable acidity during storage. From initial level of 3.6% the acidity decreased in all the treatments during storage. The maximum change was recorded in T_1 (3.01%) after 190 days of storage and minimum change was recorded in T_4 (3.22%) after 190 days of storage. Difference between T_1 and T_3, T_2 and T_4 were significant.

From the above finding in all the three fruits under study it is evident that there is a decreasing trend in acidity during storage in all the packing materials, although the rate of decrease was different in all the treatments. T_4 showed the minimum change so it can be ranked as best, followed by T_3. (Decrease in acidity may be due to the loss of SO_2 from the fruit samples during storage which were dipped in KMS solution before drying. Potassium salts might have combined with the acids thereby decreasing the acidity during the storage.) Kikon (1975) observed the decrease in acidity during storage of apple.

4. Standardisation of syrup strength for reconstitution

It may be seen from the data in Table 18 that the optimum syrup strength for reconstituting the dehydrated banana and mango chips was 25% whereas it was 30% in jackfruit.

5. Organoleptic qualities of reconstituted banana, mango and jackfruit

Packing materials have got a pronounced effect on the organoleptic properties of the product. Dehydrated banana chips stored in craft paper bags remained good upto 70 days of storage and for 130 days of storage, the product became unacceptable. In butter paper bags, the product became unacceptable after 110 days. In polythene and polypropylene bags, the product was acceptable upto 170 days.

In reconstituted banana powder, craft paper bags was not acceptable beyond 130 days of storage. Polythene and polypropylene packed materials remained good even after 190 days of storage.

Data on the reconstituted mango chips in Table 21 showed the influence of packing materials in organoleptic properties. Polythene and polypropylene packed materials could be accepted upto 130 days of storage while craft paper bags and butter paper packed materials remained good upto 70 days of storage.

Similarly in the reconstituted mango powder, the craft paper packed materials was acceptable upto 170 days of storage while polythene and polypropylene packed materials remained good throughout the storage period.

From the data presented in Table 23, it is seen that the packing materials and storage period have pronounced influence in the organoleptic qualities of the reconstituted banana chips. Craft paper bag packed materials was not acceptable beyond 130 days of storage but polythene and polypropylene remained good upto 150 days of storage and acceptable upto 190 days of storage.

In reconstituted jackfruit powder, craft paper and butter paper bag packed materials were good upto 70 days of storage while polythene and polypropylene packs showed good results upto 190 days of storage. Thus all the three fruits under study showed a similar trend in the organoleptic quality, showing different performance in all the treatments which was also influenced by the storage period. The difference in the organoleptic qualities in different treatments may be due to the presence of status of volatile components in the fruit tissue. There may be gradual reduction in volatile flavour compounds during the storage. Mostly organic acids, which contribute flavour and taste characteristics might have been lost gradually during storage. Further investigation is needed in this regard.

6. <u>Pest and diseases</u>

While storing the dehydrated banana, mango and jack-fruit, there was no incidence of the pest and diseases in the product. This may be due to the fact that the available water in the product was low thereby microbial activity was inhibited. So the product should be kept in a cool dry place.

Summary

SUMMARY

The studies described herein were conducted with the objective of standardising a suitable method of dehydrating and storing three of our popular fruits which can retain their natural flavour as well as quality to the maximum extent. It also included the pre-storage preparation and treatments of fruits to improve the storage life. The salient results obtained from the investigations are summarised below.

The fruits prepared for storage by peeling and cutting were treated with KMS solution for two hours whereby they absorbed the preservative. Two methods of drying were tried in the experiments viz., sundrying and mechanical drying. It showed that the former is not satisfactory in that the material remained pulpy even after 25 days of sundrying. The moisture level of fruits came down to satisfactory levels by mechanical drying. The drying ratio was minimum for banana and maximum for mango and this was related with the initial moisture levels. The product showed browning after 48 hours of drying. The time of drying, varied with fruits - banana taking 87 hours, jack 84 hrs and mango 80 hrs.

The storage conditions provided for the prepared fruit materials influenced the keeping quality. Materials packed in craft paper bags, butter paper bags, polythene bags and polypropylene bags and open storage conditions were found to

be quite unsatisfactory, as there was serious quality deterioration due to fermentation which was started by 50 days after storage. Storage inside a steel trunk proved effective. This method was adopted for further studies.

The effect of packing materials on the chemical constituents of the product were analysed. In the case of banana, mango and jack, a minimum change in moisture content from zero storage conditions were noticed in polythene and polypropylene bags. The T.S.S. content of all the fruits increased in storage, with fruits stored in polypropylene and polythene bags recording minimum change. In banana, the T.S.S. content after 190 days of storage was recorded as 39% in craft paper bags while the polypropylene stored samples recorded 37.4% only. In mango, from the initial level of 28.5%, T.S.S. changed to 34.2% in craft paper storage, while it was 33% in polypropylene bags after 190 days. Jack fruit stored in different packing materials also indicated an increase in T.S.S. with duration of storage. From the initial 47%, it increased to 49.76%, stored in craft paper bags while a minimum change to 48.95% occurred in polypropylene bags.

The total sugar present in the fruit material also indicated a gradual increase with storage. In banana, maximum change from initial level of 17.49% was observed when craft paper was used for storage (25.38%) and minimum change was observed when polypropylene bags were used (24.15%). In mango, total sugar increased from 21.65% to 24.2% in craft paper bags and to 23.15% in polypropylene bags. Other two packing materials indicated intermediate change. Similar trends were observed in jack fruit also where the maximum change was from 29.5% to 36.6% in craft paper bags and minimum change was from 29.5 to 35.22% in polypropylene bags.

The percentage of reducing sugar also increased during storage in all the fruit materials with the range varying with packing materials. Here also maximum changes were noticed in fruit materials stored in craft paper bags and minimum changes in fruit materials kept in polypropylene bags.

The titrable acidity decreased with the storage in all the fruit samples. The extent of reduction was dependent on the nature of package used. In all the fruit samples, the lowest titrable acidity was recorded from those stored in craft paper bags while the least change in acidity was observed in polypropylene bags. The syrup strength for reconstituting the fruit materials stored as dried chips were standardised. For mango and banana 25% sugar syrup was best while for jack 30% syrup was best.

The organoleptic tests for the fruit materials stored as chips indicated that the fruits stored in craft paper bags remained acceptable upto 70 days, upto 110 days in butter paper bags and upto 170 days in the other two packing materials in the case of banana. The banana powder when reconstituted, remained good upto 90 days in craft paper bags and upto 110 days in butter paper bags. Banana powder stored in polythene and polypropylene retained quality even after 190 days. The mango chips remained acceptable till 70 days in craft and butter paper bags. In polythene and polypropylene bags it remained acceptable upto 130 days. The stored mango powder was acceptable upto 110 days in craft paper bags and upto 130 days in butter paper bags. The polythene and polypropylene storage were excellent upto 90 days and remained good throughout the storage period. The jack fruit chips stored in craft paper bag remained acceptable till 90 days of storage; butter paper was also good upto 90 days. The other two types of packages were good upto 150 days and remained acceptable throughout the storage period. The reconstituted jack fruit powder was good upto 70 days in craft paper and butter paper bags and upto 130 days in polythene and polypropylene bags. Incidence of pest and diseases were not observed during the storage.

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*Original not seen

Appendices

Appendix I

Weather data for the period from March 1982 to May 1982

Month	Temperature °C		Relative humidity (%)		Sunshine hours	Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum		
March						
1st week	34.9	22.1	86.1	49.1	9.8	-
2nd week	36.9	21.6	88.1	67.7	9.5	-
3rd week	35.7	23.5	86.5	83.8	7.3	-
4th week	33.9	25.9	80.6	79.2	8.3	-
weekly average	35.4	27.2	85.32	69.95	9.3	
April						
1st week	35.0	25.6	84.3	85.0	8.5	-
2nd week	35.2	25.0	79.3	86.6	10.0	-
3rd week	35.3	24.3	82.1	61.7	9.1	32.2
4th week	34.3	26.0	87.2	87.2	8.3	13.0
Weekly average	34.7	25.4	83.22	80.12	9.1	
May						
1st week	33.7	25.5	87.4	79.5	7.7	6.0
2nd week	35.7	24.8	85.2	55.2	9.4	4.7
3rd week	33.7	23.6	87.9	70.1	6.8	128.4
4th week	33.0	24.4	92.1	78.2	4.9	-
	33.8	24.5	88.15	70.75	7.3	

Appendix II

Analysis of variance for the effect of different packing materials and storage period

Storage period (days)	Source	df	Mean sum of square Moisture		
			Banana	Mango	Jack
50	Treatment (T)	3	0.88**	0.35**	0.22**
70	T	3	0.74**	1.46**	2.47**
90	T	3	1.77**	2.54**	4.03**
110	T	3	3.56**	5.76**	4.53**
130	T	3	9.48**	5.46**	5.50**
150	T	3	10.33**	7.34**	4.65**
170	T	3	11.75**	7.70**	6,09**
190	T	3	11.18**	9.05**	8.14**

** Significant at 1 per cent level

Appendix III

Analysis of variance for the effect of different packing materials and storage period

Storage period (days)	Source	df	Mean sum of square T.S.S. Banana	Mango	Jack
50	Treatment (T)	3	0.56	2.17	0.53**
70	T	3	0.69**	4.23	0.47**
90	T	3	0.66**	2.25	1.41**
110	T	3	1.07**	3.13	2.05**
130	T	3	0.87**	3.16	2.04**
150	T	3	1.04**	2.30**	1.62**
170	T	3	1.8**	1.83**	1.84**
190	T	3	2.76**	1.34**	1.36**

** Significant at 1 per cent level

Appendix IV

Analysis of variance for the effect of different packing materials and storage period

Storage period (days)	Source	df	Mean sum of square Total sugar		
			Banana	Mango	Jack
50	Treatment (T)	3	0.19**	0.04*	2.73**
70	T	3	0.40**	0.113**	2.76**
90	T	3	0.26	0.646**	2.36**
110	T	3	0.11**	1.0**	2.64**
130	T	3	0.36**	1.42**	2.36**
150	T	3	0.65*	1.28**	1.76**
170	T	3	1.77**	1.44**	1.60**
190	T	3	1.78**	1.79**	1.72**

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix V

Analysis of variance for the effect of different packing materials and storage period

Storage period (days)	Source	df	Mean sum of square Reducing sugar		
			Banana	Mango	Jack
50	Treatment (T)	3	0.11**	1.44**	1.31*
70	T	3	0.23**	1.46**	2.98**
90	T	3	0.25**	1.03**	7.04**
110	T	3	0.42**	0.67**	7.08**
130	T	3	1.03**	1.23**	6.85**
150	T	3	0.72**	1.50**	7.19**
170	T	3	1.09**	1.16**	6.42**
190	T	3	1.43**	1.22**	7.93**

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VI

Analysis of variance for the effect of different packing materials and storage period

Storage period (days)	Source	df	Mean sum of square		
			Acidity		
			Banana	Mango	Jack
50	Treatment (T)	3	0.002**	0.028**	0.009**
70	T	3	0.003**	0.006**	0.012**
90	T	3	0.001**	0.01**	0.013**
110	T	3	0.001**	0.063**	0.028**
130	T	3	0.002**	0.09**	0.037**
150	T	3	0.002**	0.03**	0.037**
170	T	3	0.004**	0.04**	0.031**
190	T	3	0.004**	0.05**	0.044**

** Significant at 1 per cent level

DEHYDRATION, PACKING AND STORAGE STUDIES OF FRUITS (BANANA, JACK AND MANGO)

By

M. KUBER SINGH

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Processing Technology
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

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ABSTRACT

A series of experiments were conducted at the College of Horticulture, Vellanikkara, with the objective of proposing a suitable method of preservation and storage of fruits, viz., banana, mango and jack. The fruit material prepared by peeling and cutting were dehydrated by mechanical drying for 80-67 hours, since sundrying was found to be unsatisfactory even after 25 days of drying. The dried materials, both as chips and powder were packed in craft paper bags, butter paper bags, polythene bags and polypropylene bags and were stored in both open air as well as closed conditions.

The samples stored in open air conditions deteriorated in quality after a short span of storage and first sign of fermentation was observed by 50th day. The packages kept in closed chamber remained without deterioration throughout the period of study.

The analysis of quality constituents such as moisture level, total soluble solids, total sugars, reducing sugars and titrable acidity indicated that the minimum change from the zero storage conditions can be obtained if the materials are stored in polythene or polypropylene bags, among the four packing materials tried. The syrup strength for reconstituting the stored materials were standardised as 25% for mango and banana and 30% for jack fruit.

The reconstituted materials were organoleptically evaluated both as such and as a preparation containing jaggery, coconut milk, spices etc. and it was found that banana chips remained acceptable upto 110 days in polythene and polypropylene bags and the powder remained good throughout. The mango chips were acceptable upto 130 days in these packages while powder was good even after 190 days of storage. The jack fruit chips stored in polythene and polypropylene bags were good upto 150 days while the powder remained acceptable even after 190 days. In all the cases where craft paper and butter paper bags were used, the fruit samples could not be stored so successfully as observed in the polythene and polypropylene bags.