Development of Nendran Banana Chips with Enhanced Shelf Life and Quality

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(2012-12-103)

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2014

DECLARATION

I, hereby declare that this thesis entitled **"Development of Nendran Banana Chips with Enhanced Shelf Life and Quality"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Dedicated to

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LIST OF ABBREVIATIONS

%	-	per cent
CD	-	Critical difference
et al	-	And others
Fig.	-	Figure
g	-	gram
kg	-	kilogram
mg	-	milligram
meq.	-	milliequivalents
^{0}C	-	Degree Celsius
i.e.	-	That is
viz.,	-	namely
CRD	-	Completely Randomized Design
CV	-	Critical value
NS	-	Nonsignificant
N	-	Newton
Ns	-	Newton seconds
FFA	-	Free fatty acid
KOH	-	Potassium hydroxide
LDPE	-	Low Density Polyethylene
MAP	-	Modified Atmospheric Packaging

Introduction

1. INTRODUCTION

Banana chips is an integral part of traditional Kerala meal, "Sadya" and also, a most popular crispy snack on various occasions. It is of high demand due to its characteristic flavour and taste. Processing of Nendran banana to chips with a longer shelf life can provide a major outlet to use surpluses as well as exploit a greater number of marketing options and Kerala has proved it.

Banana chips are prepared from mature unripe fruits by frying the slices in oil. During deep frying, the oil is exposed to atmospheric oxygen, high temperature and moisture released from the food and it enters the food, provides nutrients and flavour. One of the major problems faced by small scale chips makers in storage of banana chips is rancidity, a condition produced by oxidation of unsaturated fats present in food, marked by unpleasant odour or flavour. When a fatty substance is exposed to air, its unsaturated components are converted into hydro peroxides which break down into volatile aldehydes, esters, alcohols, ketones and hydro carbons, some of which have disagreeable odours.

Shelf life is a major consideration in developing, producing and marketing banana chips. Consumers desire products that maintain a fresh appearance, odour and flavour for as long as possible and a longer shelf life reduces costs for the producer and ultimately for the consumer. Antioxidants are often added to fat containing foods in order to delay the onset or slow the development of rancidity due to oxidation. The main characteristic of an antioxidant is its ability to trap free radicals.

Antioxidants play an important role in preventing undesirable changes in flavour, nutritional quality of foods and protect the cells against tissue damage associated with various human diseases (Arai *et al.*, 2000). Synthetic antioxidants such as butylated hydroxyl anisole (BHA), butylated hydroxy toluene (BHT) and propyl gallate (PG) are widely used as food additives, but their application has been reassessed because of possible toxic or carcinogenic components formed during their degradation (Namiki, 1990). A recent area of interest in antioxidant research is concerned with finding effective replacements for the conventional synthetic antioxidants from among various natural plant extracts which are seen to possess antioxidant properties.

The entire tissues of fruits and vegetables is rich in bio-active compounds such as phenolic compounds, carotenoids, flavonoids, anthocyanins, vitamins and in most cases the waste products can present similar or even higher amounts of antioxidant and antimicrobial compounds (Ayala-Zavala *et al.*, 2004). Agricultural residues like potato peel (Larrosa *et al.*, 2002), banana peel (Nguyen *et al.*, 2003), water melon peel (Zeyada *et al.*, 2008), cucumber peel (Hemalatha and Ghafoorunissa, 2007) etc. are rich sources of antioxidants.

Flavor imparting substances like black pepper (Reshmi *et al.*, 2010), garlic (Santhosha *et al.*, 2013), curry leaf (Biswas *et al.*, 2006), coriander (Sultana *et al.*, 2010) etc. are also reported to have antioxidant properties. Research on the use of these flavour imparting substances having antioxidant properties on food products are gaining momentum, which can also combat lack of variety in banana chips. Chips makers are seeking for such materials which could attract the snacking behavior of all age groups.

The keeping quality of banana chips is of much economic importance since these are widely used and are often stored for extended periods before consumption. The quality is greatly affected when exposed to light, moisture and air and hence ideal packaging and storage conditions have to be maintained for extending the shelf life. So, the present investigation "Development of Nendran banana chips with enhanced shelf life and quality" was carried out with the following objectives

1. To evaluate and compare the effect of natural antioxidants in delaying rancidity of banana chips during storage.
2. To explore the possibility of developing flavoured chips with extended shelf life.

Review of literature

2. REVIEW OF LITERATURE

The present study focus on the effect of natural antioxidants in enhancing the shelf life and quality of banana chips. This chapter describes the review of related research and development activities done in the past few years.

Fried banana chips are a deep fried snack food prepared from green fresh mature bananas of the cooking variety. The aim of deep fat frying is to seal the food surface by immersing food pieces in the hot oil so that all flavours and juices are retained inside. Frying causes changes in physical and chemical properties including starch gelatinisation, protein denaturation, water vapourisation and crust formation (Mallikarjunan *et al.*, 1997). The high temperature causes partial evaporation of water, which moves away from the food and through the surrounding oil (Khalil, 1999).

Production and marketing of banana chips is principally a small scale food business of South Kerala. It can be consumed in between meals as much as desired which could provide sufficient amount of micronutrient in the diet. An average serving of 45 g chips per day provide 23.0% and 31.1% iron, 20.1% and 14.6% zinc and 2.61 retinol equivalents (RE) daily for adult male and female respectively. It may potentially be used in intervention programmes to combat micronutrient deficiencies by virtue of their iron, zinc and total carotenoid content (Adeniji and Tenkouana, 2007). Fried banana chips are prepared by peeling and slicing fully matured but unripe bananas and deep-fat frying the slices in suitable edible oil or fat, or combinations thereof (Adeniji *et al.*, 2010).

2.1. RANCIDITY

Oil is used as a heat transfer medium during the frying process. It get absorbed and becomes a major part of the finished product. All fats are subjected to deterioration by oxidative and hydrolytic rancidity, which is the major mode of deterioration of all fried snack foods. Increase in unsaturated fat leads to increase in rancidity (Dopico, 2000).

Rancidity is a condition produced by oxidation of unsaturated fats present in food, marked by unpleasant odour or flavor. The word 'rancid' is derived from Latin word '*rancidus*' means stinking. Oils can be particularly susceptible to rancidity because of their chemistry which makes them susceptible to oxygen damage. Oxidative rancidity occurs when the double bonds of an unsaturated fatty acid react chemically with oxygen. Normally, bonds would not split in a way that leaves a molecule with odd unpaired electrons. However, when weak bond split, free radicals are formed. Frec-radicals are very unstable and react quickly with other compound trying to gain stability. Generally, free radicals attack the nearest stable molecules and gain its electron to attain stability. When the attacked molecule loses its electron, it becomes a free-radical itself, these formations of free-radicals continues and finally result in the disruption of the substance especially in fatty foods (Borek, 1991).

Reactive oxygen species (ROS) such as singlet oxygen, superoxide anion, hydroxyl radical and hydrogen peroxide (H_2O_2) are often generated as by-products of biological reactions or from exogenous factors. These free radicals may oxidize nucleic acids, proteins, lipids or DNA and can initiate degenerative disease. When a fatty substance is exposed to air, its unsaturated components are converted into hydro peroxides, which break down into volatile aldehydes, esters, alcohols, ketones and hydrocarbons which destroys nutrients in food and produce disagreeable odours as well as harmful to health (Byrd, 2001).

Lipid oxidation is a major deteriorative reaction in frying oils and fried foods, and often leads to changes in functional, sensory and nutritive values which reduces the consumer acceptance of product (Velasco *et al.*, 2002). Many of the degenerative diseases of ageing including cancer, cardiovascular diseases, cataract and other diseases resulting from long-term exposure to free radicals (Abdullahi, 2011).

One of the factors that contribute significantly to the quality of the final product is the frying medium. Degradation of the frying medium, which is absorbed into chips, depends strongly on the presence of unsaturated fatty acids. Vegetable oils that have a high content of polyunsaturated fatty acids from a higher ratio of oxidised products during frying compared with oils that have high oleic acid and saturated fatty acid content. Lipid oxidation is a major deteriorative reaction in frying oils and fried foods and often results in a significant decrease in quality (Allam and El-Sayed, 2004).

Hydrolytic, ketonic as well as oxidative rancidity occurs in coconut oil of which oxidative rancidity produces mild odour compared to the other two (Seneviratne *et al.*, 2005). Commercial coconut oil prepared by pressing copra and homemade coconut oil prepared by boiling water extracts of scrapped coconut kernel were analysed to study the effect of method of extraction on oxidative stability and it was found that commercial coconut oil was more prone to lipid oxidation and rancidity development (Seneviratne *et al.*, 2005). Compared to unrefined copra oil, rancidity problem was very less in virgin coconut oil. A low peroxide value of 0.21 – 0.57 meq O_2 / kg signified high oxidative stability of virgin coconut oil (Marina, *et al.*, 2009). Natural antioxidants and pigments in oilseeds lead to extended shelf life and hence better oxidative stability (Oyedeji and Oderinde, 2006).

Even if we take sufficient care in handling vegetable oils like use of stainless steel equipment, airtight packaging, refrigeration, protection from light addition of antioxidants etc. rancidity and all its associated deleterious changes may occur. The onset of rancidity may be delayed substantially by fortification with antioxidants, but it cannot be stopped completely and once deterioration starts to occur, the process will accelerate (Lindley, 1998).

2.2. ANTIOXIDANTS

Antioxidants have been added to frying media to improve the shelf life of deep fried snack food products (Stuckey, 1968). Antioxidants are the substances that are able to prevent or inhibit oxidation processes in human body as well as in food products. The protection of foods from oxygen is the basic principle upon which antioxidant protective technologies are based. Oxidation is a chemical reaction that transfers electrons from a substance to an oxidizing agent. Oxidation reactions can produce free radicals, which start chain reactions that damage cells. Antioxidants terminate these chain reactions by removing free radical intermediates and inhibit other oxidation reactions by being oxidized themselves. As a result, antioxidants are often reducing agents such as thiols, ascorbic acid or polyphenols (Sies, 1997).

Antioxidants are grouped into primary or natural antioxidants and secondary or synthetic antioxidants. Primary or natural antioxidants are the chain breaking antioxidants which react with lipid radicals and convert them into more stable products. Antioxidants of this group are mainly phenolic in structure and include the following (Hurrell, 2003). Antioxidant minerals, which are co-factor of antioxidant enzymes and their absence will definitely affect metabolism of many macromolecules such as carbohydrates. Examples include selenium, copper, iron, zinc and manganese. Antioxidant vitamins, which are needed for most body metabolic functions. They include-vitamin C, vitamin E, vitamin B. Phytochemicals are phenolic compounds that are neither vitamins nor minerals like, flavonoids that give vegetables fruits, grains, seeds leaves, flowers and bark their colours, catechins are the most active antioxidants in green and black tea and sesamol and carotenoids are fat soluble colours like beta carotene, lycopene in fruits and vegetables and zeaxantin especially in spinach and other dark greens.

Secondary or synthetic antioxidants include Butylated hydroxy anisole (BHA), Butylated hydroxyl toluene (BHT), Propyl gallate (PG), metal chelating agent (EDTA), Tertiary butyl hydroquinone (TBHQ) and Nor dihydro guaretic acid (NDGA).

Noor and Augustin (2006) studied the effectiveness of antioxidants on stability of banana chips and found that chips fried in refined bleached and deodorised olein containing BHA or BHT were more stable than chips fried in RBD olein without antioxidants. BHT was more effective than BHA in prolonging the shelf life of banana chips.

2.2.1. Mechanism of Action of Antioxidants

Propagation and initiation of free radicals chain reaction can be delayed or minimized by the donation of hydrogen from the antioxidants and metal chelating agent. The major antioxidants currently used in foods are monohydroxy or polyhydroxy phenol compounds with various ring substitutions. These compounds have low activation energy to donate hydrogen. Hence, the resulting antioxidant free radical is not subjected to rapid oxidation due to its stability. Antioxidant's free-radicals can also react with lipid free radicals to form a stable complex compound thereby preventing some of their damages.

Two principle mechanisms of action have been proposed for antioxidants. The first is a chain-breaking mechanism by which the primary antioxidants donate electrons to the free radicals present in the system, example lipid radicals. The second mechanism involves removal of ROS (reactive oxygen species) and RNS (reactive nitrogen species) initiator by quenching chain initiator catalyst (Hamid *et al.*, 2010).

2.2.2. Antioxidants in Food Preservation

The antioxidant supplementation is a generally accepted method of prolonging the stability and storage life of food products in particular the ones including fat. Antioxidants are often added to fat containing foods in order to delay the onset or slow the development of rancidity due to oxidation. The main characteristic of an antioxidant is its ability to trap free radicals.

Antioxidants play an important role in preventing undesirable changes in flavor, nutritional quality of foods and protect the cells against tissue damage associated with various human diseases (Arai *et al.*, 2000). Synthetic antioxidants such as butylated hydroxyl anisole (BHA), butylated hydroxy toluene (BHT) and propyl gallate (PG) are widely used as food additives, but their application has been reassessed because of possible toxic or carcinogenic components formed during their degradation (Namiki, 1990). So the need for more natural and safe antioxidants got increased and several gave promising results in food industry. A recent area of interest in antioxidant research is concerned with finding effective replacements for the conventional synthetic antioxidants from among various natural plant extracts which are seen to possess antioxidant properties.

2.3. NATURAL ANTIOXIDANTS

Vegetable materials contain many compounds with antioxidant activity. Several plants have been studied as sources of potentially safe natural antioxidants for the food industry; various compounds have been isolated, many of them being polyphenols. A large range of low and high molecular weight plant polyphenols presenting antioxidant properties has been studied and proposed for protection against lipid oxidation (Parr and Bowell, 2000). Most naturally occurring phenolic compounds are present as conjugates with mono and polysaccharides, linked to one or more of the phenolic groups and may also occur as functional derivatives such as esters and methyl esters (Harborne *et al.*, 1999). Such structural diversity results in the wide range of phenolic compounds which can be categorised as benzoquinones, hydroxy benzoic acids, acetophenones, phenyl acetic acids, naphthoquinones, antraquinones, flavonoids, iso - flavanoids, lignans, lignins, tannins etc. Of these, phenolic acids, flavonoids and tannins are regarded as the main dietary phenolic compounds (Hamid *et al.*, 2010).

The antioxidant activity of phenolic compounds is due to their ability to scavenge free radicals, donate hydrogen atoms or electron, or chelate metal cations (Amarowicz *et al.*, 2004). The structure of phenolic compounds is a key determinant of their radical scavenging and metal chelating activity and this is referred to as structure – activity relationships (SAR). The high potential of polyphenols to scavenge free radicals may be due to their many phenolic hydroxyl groups (Sawa *et al.*, 1999). The possible health benefits derived from dietary phenolic compounds depend on their absorption and metabolism (Parr & Bolwell, 2000), which in turn are determined by their structure including their conjugation with other phenolics, degree of glycosilation/acylation, molecular size and solubility (Bravo, 1998).

Different studies have shown that free radicals present in the human organs cause oxidative damage to various molecules such as lipids, proteins and nucleic acids and are thus involved in the initiation phase of degenerative diseases. Phenolic and other phytochemical antioxidants found in fruits and vegetables are capable of neutralizing free radicals and may play a major role in prevention of certain diseases (Kaur and Kapoor, 2001). The chemical activities of polyphenols in terms of their reducing properties as hydrogen or electron-donating agents predicts their potential for action as free-radical scavengers. The activity of an antioxidant is determined by its reactivity as a hydrogen or electron-donating agent (which relates to its reduction potential), the fate of the resulting antioxidant-derived radical, which is governed by its ability to stabilize and delocalize the unpaired electron, its reactivity with other antioxidants and the transition metal-chelating potential (Shahidi and Wanasunadra, 1992).

Natural antioxidants have been proven effective in retarding peroxide formation in cotton seed and soya bean oil absorbed in fried bread cubes, during storage of cubes at 60^0C (Tian and White, 1994). Tocopherol is an antioxidant that occurs in vegetable oils that extends the initiation period of auto – oxidation and deterioration of fried oils. (Ferrari *et al.*, 2004). Fortification with natural antioxidants (culinary herbs) was used to inhibit lipid oxidation in raw and cooked minced meat patties during storage (Souzan *et al.*, 1999). Spices and vegetables possess antioxidant activity that can be applied for preservation of lipids and reduce lipid peroxidation in biological systems (Sobhana and Naidu, 2000).

2.3.1. Natural Antioxidants from Processing Waste

Vegetables and some fruits yield between 25% and 30% of non-edible products (Ajila *et al.*, 2010). The failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of natural resources (Bhalerao *et al.*, 1989). Direct relationship exists between the total phenolic contents and the antioxidant activities in fruits and vegetables (Liu *et al.*, 2002). The entire tissue of fruits and vegetables are rich in bio-active compounds, such as phenolic compounds, caroteinoids, flavonoids, anthocyanins, vitamins and in most cases the waste by-products can present similar or even higher contents of antioxidant and antimicrobial compounds (Ayala-Zavala *et al.*, 2004).

The waste materials such as peels, seeds and stones produced from the fruit and vegetable processing unit can be successfully used as a source of phytochemicals and antioxidants. Higher amount of phenolic compounds and ascorbic acids has been reported in the peel than in pulp (Goulas and Manganaris, 2012) and in green form than in ripe (Fatemeh *et al.*, 2012) for most of the fruits. The majority of fruit peels exhibited 2 to 27 fold higher antioxidant activity than the fruit pulp (Guo *et al.*, 2003). Edible pulp of bananas (*Musa paradisiaca*) contain 232 mg/100g of dry weight phenolic compounds, which is about 25% of that present in the peel (Someya *et al.*, 2002).

Residues from star fruit (Shui and Leong, 2006), grape pomace (Lafka *et al.*, 2007), citrus fruits peel (Xu *et al.*, 2008), by-products from pomegranate (Singh *et al.*, 2002) and banana peel (Gonzalez-Montelongo *et al.*, 2010) have been evaluated as inexpensive sources of antioxidants.

2.3.1. a. *Banana Peel as Natural Antioxidant*

Banana, a tropical plant may protect itself from the oxidative stress caused by strong sunshine and high temperature by producing large amounts of antioxidant (Kanazawa and Sakakibara, 2000). Banana peel, an underutilized source of phenolic compounds is considered as a good source of antioxidants for foods and functional foods against cancer and heart disease. Polyphenolic content of banana peel ranges from 0.90g – 3.0g/100g dry weight (Nguyen *et al.*, 2003). The peel of the fruit contains various antioxidant compounds such as gallocatechin (Kanazawa and Sakakibara, 2000) and dopamine (Someya *et al.*, 2002).

The antioxidant effects of crude extracts from green banana and yellow peel were investigated and the results indicated that the extract of green banana peel recorded more significant activities than that of yellow peel. Green banana peel displayed high antioxidant activity as measured by ß-carotene bleaching method, DPPH free radical and linoleic acid emulsion. The results showed that the inhibitory activity of 70% acetone extracts of green banana peel using thiocyanate method at concentration of 0.5 mg ml^{-1} was close to the synthetic antioxidant reagent of BHA at 0.1 mg ml^{-1} (Mokbel and Hashinaga, 2005).

The influence of stage of ripeness (green and ripe) and parts (pulp and peel) on antioxidative compounds and antioxidant activity of banana fruit was investigated by Fatemeh *et al.* (2012). Total phenolic content (TPC) and total flavonoid content (TFC) values of banana peel were higher than those of banana pulp. Also, green banana showed higher TPC and TFC values than those of ripe fruit. Radical scavenging activities (inhibition of DPPH) of the extracts ranged from 26.55 to 52.66%.

Ethyl acetate and water soluble fractions of green banana peel displayed high antioxidant activity. Glycoside and monosaccharide components isolated from water soluble extracts displayed significant antioxidant activity whereas compounds like β – sitosterol, malic acid, 12-hydroxystearic acid and succinic acid showed significant antibacterial activities and low antioxidant activities.

Antioxidant components and antioxidant activity of three varieties of banana namely 'Pachabale', 'Yelakkibale' and 'Nendrabale' were determined (Nagarajaiah and Prakash, 2011). Higher free radical scavenging activity (90%) was reported in Nendrabale peel in ethanolic extract compared to aqueous (64%) and methanolic extract (62%). Among the three varieties Nendrabale peel exhibited higher antioxidant activity.

2.3.1. b. *Potato Peel as Natural Antioxidant*

Potato peel, a waste by-product from potato processing, could be considered as a new source of dietary fibre, polyphenols and natural antioxidant. The antioxidant activity of potato peel extract has been studied in food systems (De Sotillo *et al.*, 1998). Mahmood *et al.* (1998) recorded that potato peel which is about 12% of their fresh weight, is usually discarded as waste (peels and trimmings).

Friedmen (1997) suggested that potato peel provides an excellent source for the recovery of phenolic compounds, as almost 50% of phenolics are located in the peel and adjoining tissues and decrease towards the center of the tuber.

The total amount of free form of chlorogenic acid and caffeic acid in the peel was highly correlated with the DPPH radical scavenging activity. Ferulic acid was identified as the active radical scavenging compound in the bound form phenolics from the peel. The potato peel may therefore offer an effective source of an antioxidant (Kazuhiro *et al.*, 2006).

The antioxidant activity was highly significant in the raw (aqueous & purified) extracts, where values between 84 & 94% were obtained for the inhibition of accelerated oxidation in pork fat, although this has not been correlated to reducing power. The purified extract displayed a greater yield in the total phenolic content compared with the aqueous extract (Souza *et al.*, 2009).

Petroleum ether extract of potato peels as natural antioxidant was evaluated during 60 days storage of refined soy bean oil at 45^0 C showed lower values of FFA (0.012, 0.109%) and peroxide values (10.0, 9.0 meq./ kg) than the control samples (FFA 0.32%, peroxide value 59 meq./ kg) as reported by Rehman *et al.* (2004).

2.3.1. c. *Watermelon Peel as Natural Antioxidant*

The therapeutic effect of water melon has been reported and has been ascribed to antioxidant compounds (Lewinsohn *et al.*, 2005). Among them, citrullin and lycopene have been demonstrated to play a prominent role in the treatment and management of ailments such as cancer and cardiovascular diseases (Rimando and Perkins – Veazie, 2005).

Zeyeda *et al.* (2008) reported that phenolic content of watermelon (9.86g/kg) was very low when compared to tomato peel phenolic content (68.79 g/kg).

Water melon peel contained different types of phenolic compounds, the most abundant one was 4 – hydroxybenzoic acid (958.3 µg/g dry weight). Incorporation of watermelon rind peel powder in cake batter, retarded staling of cakes and inhibits lipid peroxidation and free fatty acids formation during storage (Al – Sayed and Ahmed, 2013).

The DPPH free radical scavenging ability of whole watermelon (with peel) fruit extract showed highest ability (81.44%) and seeds least ability (56.93%) as reported by Oseni and Okoye (2013).

2.3.1. d. *Cucumber Peel as Natural Antioxidant*

Cucumber peel is considered as a cheap source of flavanoid and can be used as a potential source of antioxidant for industrial applications (Agarwal *et al.*, 2012).

Zeyeda *et al.*(2008) studied the phenolic content of some selected vegetable wastes and reported them in descending order as olive leaves > tomato peel > orange peel > cucumber peel > watermelon peel > potato peel. The major phenolic compounds in cucumber peel were identified by them as chlorophyll, pheophytin, phellandrene and caryophyllene with amounts ranging from 1.21 – 3.46 mg/g. Chlorophyll and pheophytins were identified with the highest amount in both cucumber and watermelon peel. Cucumber peel powder even at higher concentration (800 ppm) had lower antioxidant activity than that produced by 200 ppm additives of TBHQ.

Crude extracts of fruits, herbs, vegetables, cereals and other plant materials rich in phenolics are increasingly of interest in the food industry because they prevent oxidative degradation of lipids and thereby improving the quality and nutritional value of food (Marja *et al.*, 1999). Many of phenolic compounds have shown strong antioxidant properties as oxygen scavengers, peroxide decomposers, metal chelating agents and free radical inhibitors. The consumption of food rich in natural antioxidants, as well as food enriched with them, ensure the desirable antioxidant status and helps in prevention of the development of diseases caused by oxidative stress (Joshi *et al.*, 2012).

2.3.2. Natural Antioxidants from Flavour Imparting Substances

Herbs and spices are added to dishes and snacks to beneficially improve the health status of the consumer without detrimental effect on flavour and taste. Spices and herbs are aromatic and pungent food ingredients with significant antioxidant activities (Suhaj, 2006). Flavours and seasonings are important considerations for snacks (Williams, 1999) and herbs could be used as both flavouring and functional ingredients (Pszczola, 1999) in snack foods. Spices are rich in phenolic compounds. The yellow colour principle present in turmeric (*Curcuma domestica*), curcumin (Narasingarao, 2003) and capsaicin (Kakar and Iwao, 1974) in capsicum are powerful antioxidants which prevent oxidation of oils and fats. Other active principles of spices such as eugenol (cloves), linalool (coriander), piperine (black pepper), zingerone (zinger) and cuminaldehyde (cumin) were reported to inhibit lipid peroxidation (Kakar and Iwao, 1974).

The potential antioxidant activities of selected spices extracts on enzymatic lipid peroxidation were investigated by Sobhana and Naidu (2000) and found that water and alcoholic extract (1:1) of commonly used spices (garlic, ginger, onion, mint, cloves, cinnamon and pepper) dose-dependently inhibited oxidation of fatty acid, linoleic acid in presence of soybean lipoxygenase. They had tested the antioxidant activity of selected Indian spices, of which, cloves exhibited highest while onion showed least antioxidant activity. The relative antioxidant activities decreased in the order of cloves, cinnamon, pepper, ginger, garlic, mint and onion. Spice mix namely ginger, onion and garlic; onion and ginger; ginger and garlic showed cumulative inhibition of lipid peroxidation thus exhibiting their synergistic antioxidant activity.

2.3.2. a. *Garlic as Natural Antioxidant*

Organosulphur compounds in garlic like s-allylcysteine and s-allylmercaptocysteine have potent antioxidant activity (Imai *et al.*, 1994). Garlic has an IC 50 value of 89.25 µg/mL (Sultana *et al.*, 2010). Okada *et al.*, 2005 reported that garlic has antioxidant and free radical scavenging activities and identifiable odours at low concentrations and suggested that a combination of allyl group ($- CH_2CH = CH_2$) and the – S(O)S - group is necessary for the antioxidant action of thiosulphates in garlic extracts.

The product derived from garlic such as aged garlic extract (AGE) is found to have a higher antioxidant activity in comparison with fresh and other commercial garlic supplements. This could be due to the extraction procedure followed, which tends to increase stable and highly bioavailable water soluble organosulfur compound content like s-allyl-L- cysteine and s-allyl mercaptocysteine with highly potent antioxidant activity. The garlic preparation is also known to contain compounds such as stable lipid soluble allyllsulfides in the form of diallylldisulfide, diallylltrisulfide and diallyllpolysulfides which exhibit antioxidant effect (Amagase *et al.*, 2001).

Asimi *et al.*, 2013 studied the antioxidant activity of some Indian spices using different methods and reported them in descending order as cumin > garlic > cinnamon > turmeric > ginger when analysed by DPPH method, garlic > cumin > turmeric > ginger > cinnamon by FRAP method and turmeric > cinnamon > garlic > cumin > ginger by TPC method. Thermal stability studies on garlic (Gazzani, 1994) and crude gingerol (Eyun and Kyu, 1993) in oils (soybean and ground nut) heated at 105–165°C showed significant antioxidant activity.

2.3.2. b. *Black Pepper as Natural Antioxidant*

Both water and ethanol extract of black pepper exhibited strong antioxidant activity (Gulcin, 2005). Chemically pepper corn contains lignans, alkaloids, flavanoids, aromatic compounds and amides (Jirovetz *et al.*, 2002). *In vitro* antioxidant activity of white and black pepper were compared by Agbor *et al.*, 2006 and reported that the hydrolysed (total polyphenol) extracts of both white and black pepper had significantly higher polyphenol concentrations than the non-hydrolysed (free phenol) extracts and so black pepper had higher antioxidant activity.

Misharina *et al.*, 2009 established that essential oils of garlic, clove bud, ginger and leaves of cinnamon have the maximal efficiency of inhibiting hexenal oxidation (80 –93%), while black pepper oil has the minimal (49%).

Pepper oil exhibited antioxidant activity during frying when used alone or in combination with capsaicin or alpha-tocopherol. It is suggested that red pepper seed oil can be used to avoid thermal oxidation instead of soybean oil during deep frying and thermal. Antioxidant potential of garlic *in vivo* and *in vitro* has been proved. Garlic is rich in selenium and organosulphur compounds, which have pronounced antioxidant activity (Hemalatha &Ghafoorunnisa, 2007).

2.3.2. c. ***Curry Leaf as Natural Antioxidant***

Sreeramulu *et al.*, 2013 studied the natural antioxidant activity and total phenolic content of selected green leafy vegetables and reported antioxidant values ranging from 21 – 1021 mg/100g and phenolic content ranging from 77 – 1077 mg/100g with curry leaves having the highest and spinach having the least. They found that curry leaves showed an increase in polyphenol content of 133% on conventional cooking, 109% on pressure cooking and 127% on microwave cooking.

Antioxidant protein compounds isolated from curry leaf was effective in scavenging free radicals at 150 fold lesser concentration compared to BHA and tocopherol (400 µM) (Biswas *et al.*,2006). Aqueous extract of *Murraya koenigii* leaves (10µg/ml) inhibited 90% of lipid peroxidation (Vandana *et al.*, 2012).

Oleoresin of curry leaves extracted using acetone was evaluated for its antioxidant activity using a β-carotene–linoleic acid model system. The oleoresin showed maximum activity of 83.2% at 100 ppm in comparison to a synthetic antioxidant, BHA which exhibited 90.2% activity at the same concentration. Two antioxidant compounds namely mahanimbine and koenigine were isolated from curry leaf (Das *et al.*, 2011).

2.3.2. d. ***Coriander as Natural Antioxidant***

Coriander extracts contain phenolics and caroteinoids which exhibit a considerable antioxidant action (De Almedia *et al.*, 2003). Coriander has an IC 50 value (58.36 µg/mL) higher than that of the ascorbic acid standard (22.78 µg/mL) as reported by Sultana *et al.* (2010).

Extracts of different polarity from leaves and seeds of coriander (*Coriandrum sativum*) and coriander oil were investigated for antioxidant activity by Wangensteen *et al.* (2004) and found that coriander leaves showed higher antioxidant activity than seeds. They suggested that addition of coriander to food will increase the antioxidant content and may have potential as a natural antioxidant inhibiting unwanted oxidation process.

Darughe *et al.* (2012) analysed chemical composition of coriander essential oil (CEO) and identified camphor (44.99%), cyclohexanol acetate (cis-2-tert.butyl-) (14.45%), limonene (7.17%) and α-pinene (6.37%). Antioxidant and antifungal activities of CEO were evaluated in cake during 60 day storage at room temperature. The results indicated that CEO at 0.05, 0.10 and 0.15% inhibited the rate of primary and secondary oxidation products formation in cake and their effects were almost equal to BHA at 0.02 % ($p<0.01$).

Sreeramulu *et al.*, 2013 reported an increase in polyphenol content of 174% on conventional cooking, 188% on pressure cooking and 211% on microwave cooking. They also reported an increase in DPPH (2, 2 – diphenyl – 1 – picryl hydrazyl) activity of 81% on conventional cooking, 101% on pressure cooking and 133% on microwave cooking of coriander leaves.

2.4. PACKAGING AND STORAGE

Several food packaging strategies are currently employed to prevent harmful oxidative reactions within food systems. Banana chips are moisture sensitive that one percentage increase in moisture level can cause considerable decrease in its crispiness and often leading to off-flavour and odour which adversely affects products shelf life (ITDI, 2007).

The shelf life of plantain chips is greatly reduced when exposed to light and air, hence must be packed in moisture proof bags to prevent absorption and loss of crispness (Stover and Simmonds, 1987).

Ogazi (1986) reported that chips packaged in polyethylene bags become rancid with time, due to reaction of oxygen from air with fat in the oil. Rancidity is manifested with colour change and taste. The typical golden yellow colour of plantain chips fades away gradually. He recommended cellophane as packaging material which is impermeable to water vapour and air.

When stability of banana (cv. 'Nendran') chips packed in polyethylene (PE), polypropylene (PP), paper/aluminium foil/polyethylene laminate (PFP), PP/Nylon/PP and metalized polyester (MP) were evaluated, banana chips stored after packing in PE and PP were acceptable up to 3 months while those in PFP, PP-Nyl-PP and MP were acceptable up to 4 months stored under ambient conditions (Roopa *et al.,* 2006).

Banana chips were packed in transparent and black polythene bags and stored in wooden cupboards and outside the box. Chips in black bags stored better than those in transparent bags irrespective of storage conditions. Similarly, chips packed in transparent polythene and stored in unlighted box had a better storage life compared to samples packed in transparent bag and exposed to light (Adeniji, 2005).

Islam and Shams-Ud-Din (2003) recommended that high density or laminated aluminum foil is suitable for long time storage of chips. The plantain chips packed in plastic sachets or in hermetic aluminum sachets can stay crispy and conserve all their quality for more than four months at room temperature and away from light. Adeniji (2005) also reported that plantain chips can be stored for up to six months with adequate packaging and storage in dark experimental cupboard to exclude light.

Addition of 0.02 % oven dried curry leaf powder to unrefined coconut oil and packaging treated chips in laminated pouches could delay rancidity of banana chips up to three months (Adrika, 2011).

Nipawan *et al.* (2012) developed an active MAP system with the incorporation of oxygen scavenger and metalized film bag for enhancing the shelf life of a traditional Thai fried banana product.

Storage stability of banana chips in polypropylene based nanocomposite packaging films were studied by Manikandan *et al.* (2012) and they reported that packaging material having 5% compatibilizer, 2% nanoclay & 100 μm thickness and 10% compatibilizer, 4% nanoclay & 120 μm thickness showed better stability.

Materials and methods

3. MATERIALS AND METHODS

The present investigation on "Development of Nendran banana chips with enhanced shelf life and quality" was undertaken at the Department of Processing Technology, College of Agriculture, Vellayani, during the period 2012-2014.

The study was carried out as three parts.

1. Effect of antioxidants on quality of banana chips.
2. Storage potential of treated banana chips.
3. Development of flavoured banana chips

3.1. EFFECT OF ANTIOXIDANTS ON QUALITY OF BANANA CHIPS

3.1.1. Preparation of Banana Chips

Fully mature unripe banana bunches of cultivar Nendran were harvested between 85 – 95 days after inflorescence emergence from Instructional Farm, Vellayani. Good sized fingers were selected, separated, washed to remove adhering dirt and dust, subsequently peels were removed and sliced using banana chips cutter into uniform slices of two mm thickness (Plate 1). Nendran banana chips were prepared in unrefined coconut oil at $165^{0}C$ with an oil- slice ratio of 2:1 by adding 0.7% salt and 0.15% turmeric as 20% aqueous solution at the end of frying (Adrika, 2011).

Two types of natural plant products having antioxidant property were incorporated into chips in two different forms by two different methods.

a. banana hands

b. peeling of fingers

c. slicing

d. adding antioxidants & frying

e. adding salt & turmeric

f. banana chips

Plate 1. Flow chart for preparation of banana chips

3.1.1. a. *Type of Plant Products*

1. Processing waste (Plate 2 & 3)

1. Banana peel	-	A1
2. Potato peel	-	A2
3. Water melon peel	-	A3
4. Cucumber peel	-	A4

Banana peel was collected from fruits and vegetable processing laboratory of Department of Processing Technology. Potato, water melon and cucumber were procured from local market, cleaned and peels were extracted using sharp knife.

2. Flavour imparting substances (Plate 4 & 5)

1. Garlic	-	A5
2. Black pepper	-	A6
3. Curry leaf	-	A7
4. Coriander leaf	-	A8

Flavour imparting substances were collected from local market, cleaned and used for the experiment.

3.1.1. b. *Form of Application*

All the above plant products were incorporated in two different forms.

F1 - Fresh form (Plate 2 & 4)

Fresh peels were cut into small bits of approximately 5mm size and flavor imparting substances were crushed.

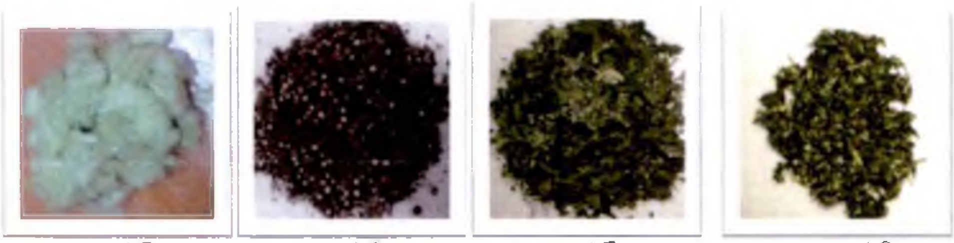
F2 - Oven dried powdered form (Plate 3 & 5)

A1 A2 A3 A4

Plate 2. Processing waste – in fresh form (F1)

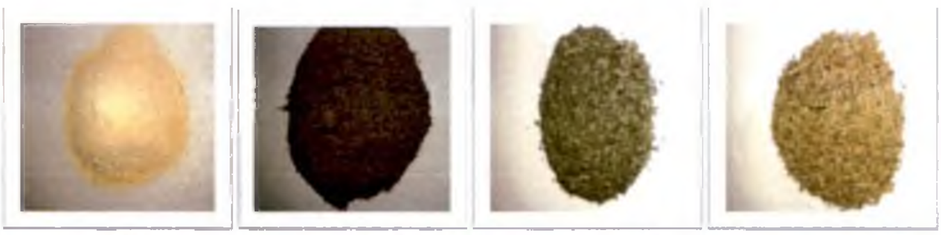
A1 A2 A3 A4

Plate 3. Processing waste – Oven dried powdered form (F2)



A5 A6 A7 A8

Plate 4. Flavour imparting substances – crushed/powdered (F1)



A5 A6 A7 A8

Plate 5. Flavour imparting substances – oven dried powdered form (F2)

Bits of fresh peel and crushed flavor imparting substances were dried at 50^0 C for 7 – 10 hours till it attains 6 – 8% moisture and powdered.

3.1.1. c. ***Method of Application***

Two types of plant products prepared in two forms were incorporated in two different ways.

M1 - Presoaking treatment of slices

Required quantity of antioxidants were added in 100 ml distilled water and the banana slices were soaked in it for 30 minutes. After 30 minutes, the slices were taken out, surface dried by spreading it on muslin cloth for 30 minutes, before frying.

M2 - Addition in frying oil

Antioxidants were added directly to oil at smoke point of 165^{0}C, before addition of the banana slices.

No: of antioxidants in each type	- 4
Concentration	- 2 (0.01 & 0.02%)
Method of application	- 2
Form of application	- 2
Total no: of treatments (4 x 2 x 2 x 2) =32	
Replication	- 2
Design	- CRD

Two experiments, each with 32 treatments were conducted separately using two sets of antioxidants. List of experiments with 32 treatment combinations, varying in antioxidant type, form, method and concentration are shown below.

Treatments with processing waste

A1F1M1C1	A2F1M1C1	A3F1M1C1	A4F1M1C1
A1F1M1C2	A2F1M1C2	A3F1M1C2	A4F1M1C2
A1F1M2C1	A2F1M2C1	A3F1M2C1	A4F1M2C1
A1F1M2C2	A2F1M2C2	A3F1M2C2	A4F1M2C2
A1F2M1C1	A2F2M1C1	A3F2M1C1	A4F2M1C1
A1F2M1C2	A2F2M1C2	A3F2M1C2	A4F2M1C2
A1F2M2C1	A2F2M2C1	A3F2M2C1	A4F2M2C1
A1F2M2C2	A2F2M2C2	A3F2M2C2	A4F2M2C2

Treatments with flavor imparting substances

A5F1M1C1	A6F1M1C1	A7F1M1C1	A8F1M1C1
A5F1M1C2	A6F1M1C2	A7F1M1C2	A8F1M1C2
A5F1M2C1	A6F1M2C1	A7F1M2C1	A8F1M2C1
A5F1M2C2	A6F1M2C2	A7F1M2C2	A8F1M2C2
A5F2M1C1	A6F2M1C1	A7F2M1C1	A8F2M1C1
A5F2M1C2	A6F2M1C2	A7F2M1C2	A8F2M1C2
A5F2M2C1	A6F2M2C1	A7F2M2C1	A8F2M2C1
A5F2M2C2	A6F2M2C2	A7F2M2C2	A8F2M2C2

Antioxidant incorporated chips were evaluated for physical, chemical, nutritional & sensory quality parameters.

3.1.2. Evaluation of Physical, Chemical and Sensory Quality Parameters

3.1.2.1. *Physical Quality Parameters*

Physical quality parameters like yield, moisture content, oil uptake, integrity and shrinkage of chips were recorded.

3.1.2.1. a. *Yield*

Weight of chips prepared from 50g fresh banana slices, were recorded in an electronic balance and yield was calculated as percentage

$$\text{Yield \%} = \frac{\text{Weight of chips after frying}}{\text{Weight of slices before frying (50g)}} \times 100$$

3.1.2.1. b. *Moisture Content*

Moisture content of one gram ground chips was estimated using moisture analyser (Plate 6), which dries the sample using a halogen lamp and gives the moisture content in percentage based on the principle of thermo gravimetric analysis.

3.1.2.1. c. *Oil Uptake*

Three gram of powder was prepared from banana chips and oil content of the powder was estimated by solvent extraction method using soxhlet apparatus (Plate 7) using 200 ml petroleum ether as solvent and expressed as percentage (AOAC, 1999).

3.1.2.1. d. *Integrity*

Ten numbers of chips were selected at random from each treatment and the number of chips which remained intact without any breakage after frying was noted and expressed as percentage over the total number.

Plate 6: Moisture analyser

Plate 7: Soxhlet apparatus

3.1.2.1. e. Shrinkage

Ten banana slices from each treatment were selected randomly. The surface area of each slice is plotted on a graph paper before and after frying. Difference in diameter was calculated and the average was worked out (Akinbode *et al.*, 2010).

$$\text{Shrinkage ratio} = \frac{[D_0 - D_t]}{D_0}$$

Where, D_0 is the diameter of fresh banana slice before frying and D_t is the final diameter of prepared chips.

3.1.2.2. *Chemical Quality Parameters*

Chemical quality parameters of banana chips viz., free fatty acid value (FFA), peroxide value and iodine value, which represent the rancidity factors of deep fried products were recorded at three months of storage.

3.1.2.2. a. *Free Fatty Acid Value*

Free fatty acid value was determined by titrating the ground chips dissolved in neutral solvent (diethyl ether and ethanol in the ratio 1:1) against potassium hydroxide, using phenolphthalein as indicator and expressed as mg KOH/g chips (Sadasivam & Manikam, 1992).

3.1.2.2. b. *Peroxide Value*

Peroxide value of the chips samples was determined by titration of powdered chips against 0.1 N thiosulphate in presence of potassium iodide using starch as indicator and expressed as milliequivalent peroxide / kg chips (Sadasivam & Manikam, 1992).

3.1.2.2. c. *Iodine Value*

A known quantity of powdered chips were treated with Hanus iodine solution and iodine value was determined by titration of treated chips against sodium thiosulphate and expressed as gram of iodine absorbed per 100 g chips (Sadasivam & Manikam, 1992).

3.1.2.3. *Sensory Quality Parameters*

Sensory evaluation of the freshly prepared banana chips were organoleptically scored by a 30 member semi trained panel comprising of research scholars of College of Agriculture, Vellayani. The panel were asked to score the appearance, colour, flavour, texture, taste and overall acceptability of the sample using a nine-point hedonic scale (ISI, 1971) (Appendix. I) in the order of preference as shown below.

Like extremely	- 9
Like very much	- 8
Like moderately	- 7
Like slightly	- 6
Neither like nor dislike	- 5
Dislike slightly	- 4
Dislike moderately	- 3
Dislike very much	- 2
Dislike extremely	- 1

Based on physical, chemical and sensory quality parameters the best quality chips were selected from each group viz. processing waste and flavour imparting substances, for further storage study.

3.2. STORAGE POTENTIAL OF TREATED BANANA CHIPS

Banana chips were prepared by incorporating the best antioxidant selected from each group. 100g of antioxidant treated and untreated chips were packed in three different packaging materials/ systems (Plate 8) and stored under ambient room temperature condition.

Packaging materials – 3

P1 - LDPE covers with 100 guage (market sample)

P2 - Laminated pouches (LDPE/Metalized polyester/LDPE)

P3 – MAP (Modified Atmospheric Packaging) in laminated pouches

Chips packed in P1 and P2 were sealed using a heat sealing machine (Quick seal ™ of Sevana (India) Ltd. Nitrogen packaging was adopted in P3 with a laboratory model modified vacuum packaging machine [Sevana's sevol v vacuum packaging machine QS 400 MG (MC)] fitted with nitrogen cylinder.

Modified atmospheric packaging machine consists of a programmable pump that creates desired percentage of vacuum inside the product chamber. The product chamber has a thermal film sealer as well as a gas flushing nozzle which can fill the product chamber with selected gas inside the product package if desired.

Preliminary setting operation of the machine were adjusted as detailed below.

Mode – 4 (Vacuum pack) and mode – 1/2/3 (Nitrogen pack)

Vacuum – 700 mm Hg

Flush 1 – 600 mm Hg (vacuum pack) and 450 mm Hg (nitrogen pack)

Flush 2 – 760 mm Hg and flush 3 – 760 mm Hg

Sealing time – 2.5 seconds

Cooling time – 9 seconds

Banana chips were packed in laminated pouches (LDPE/metalised polyester/LDPE) and kept inside the product chamber of the machine in such a

P1- LDPE covers

(market sample)

P2- Laminated pouches

(LDPE/ Metalised polyester/ LDPE)

P3 – MAP in laminated pouches

Modified Atmospheric Packaging machine

Plate 8: Different packaging materials / systems

way that the opening of pouch was covered by a gas flushing nozzle and the sealing bars could seal the pouches properly. When the acrylic lid was closed and gently pressed vacuum pump evacuated air inside the chamber and flushed nitrogen gas into the package. The pouch opening was hermetically sealed by a heat impulse transmitted by the bar resistance and cooled. When the lid of product chamber was automatically opened the packaged product was taken out.

Antioxidants - 3

A1 - Best antioxidant selected from processing waste

A2 - Best antioxidant selected from flavour imparting substances

A3 - Control (No antioxidants)

Packaging materials - 3

Total number of treatments - 3 x 3 = 9

Replication - 3

Design - CRD

Sample size - 100 g

The prepared chips were evaluated for the following physical, chemical and organoleptic parameters at the time of storage and at fortnightly intervals for a period of three months.

3.2.1. Physical Quality Parameters

Physical quality parameters viz., moisture content, colour and texture of banana chips were recorded at the time of storage and at periodic intervals for three months.

3.2.1. a. *Moisture Content*

Moisture content of chips was estimated at 15 days interval as described in 3.1.2.1.b.

3.2.1. b. *Colour*

Colour of treated and untreated banana chips was recorded at monthly intervals using spectrophotometer (Plate No: 9) as yellowness index using the $L^*a^*b^*$ color indices, adopted by the Commission Internationale d'Eclairage. The captured images of the products were converted to graphs using computer program from which the following colour indices were obtained.

L^* - luminance or lightness

a^* - greenness to redness

b^* - blueness to yellowness.

Yellowness index was computed using the formula

$$\text{Yellowness index} = 142.86 \times [b \div L]$$

3.2.1. c. *Texture*

Texture of the prepared banana chips was measured as crispness, hardness and toughness using a food texture analyzer (TAHD-Stable Microsystems, UK) (Plate No: 10) at monthly intervals by snap test method. Sample was placed on a heavy duty platform with a crisp support rig in the centre. When lowered, the spherical stainless steel ball probe of 0.25 inch, passed centrally through the sample kept on crisp support rig and a corresponding force deformation curve (Fig 1.) was plotted.

Crispness was obtained as the count of peaks in the graph and toughness (expressed in Newton seconds-Ns.) by the area of the graph. Hardness (expressed in Newton-N) which indicates the force required by the probe to break the chips was obtained at the Y – axis corresponding to highest peak in the graph (Akinbode *et al.*, 2010).

Plate 9. Food texture analyzer

Plate 10.Spectrophotometer assembly for colour measurement

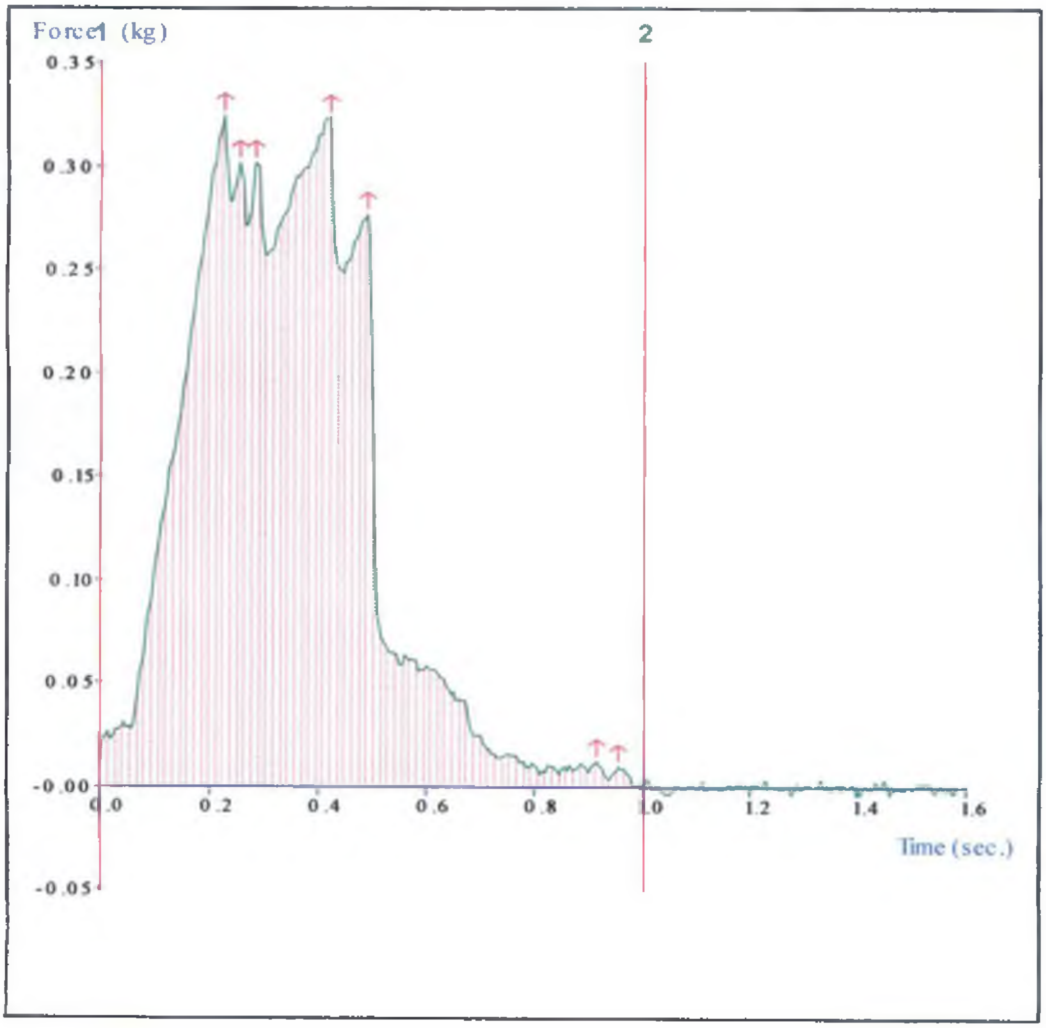


Figure 1. Typical force-deformation curve of banana chips as measured by Food Texture Analyser

3.2.2 Chemical Quality Parameters

Chemical quality parameters of banana chips viz., Peroxide value, Free fatty acid value and Iodine value were recorded at fortnightly intervals and total antioxidant activity at monthly intervals for a period of three months.

3.2.2. a. *Free Fatty Acid Value*

Free fatty acid value of stored chips was determined as detailed in 3.1.2.2.a.

3.2.2. b. *Peroxide Value*

Peroxide value of the stored chips was determined as detailed in 3.1.2.2.b.

3.2.2. c. *Iodine Value*

Iodine value of stored chips was determined as detailed in 3.1.2.2.c.

3.2.2. d. *Total Antioxidant Activity*

Total antioxidant activity of stored banana chips was determined using 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured according to the procedure of Shimada *et al.* (1992).

2.0 ml sample was added to 2.0 ml 0.1mM DPPH solution, shaken the mixture and left for 30 minutes at room temperature. The absorbance was read at 517nm. Scavenging effect was expressed as % inhibition of DPPH as shown in the following equation:

$$\% \text{ inhibition of DPPH} = \frac{[A_{blank} - A_{sample}]}{A_{blank}} \times 100$$

Where,

A_{blank} - Absorbance of DPPH solution without sample, read against ethanol blank

A_{sample} – Absorbance of the test sample

3.2.3. Sensory Quality Parameters

Sensory quality parameters of antioxidant treated chips were organoleptically scored as described in 3.1.2.3 at fortnightly intervals for a period of three months.

Based on superior physical, chemical and sensory quality parameters the treatments which produced best quality chips with maximum shelf life was selected.

3.3 DEVELOPMENT OF FLAVOURED BANANA CHIPS

3.3.1. Preparation of Flavoured Banana Chips

For full filling the objective of developing flavoured banana chips, flavor imparting substances like garlic (G), black pepper (Bp), curry leaves (C) and coriander leaves (Co) were added directly to frying oil during preparation of chips (Adrika, 2011) as detailed below.

3.3.1. a. ***Concentrations Tried***

C1 - 1% and C2 - 2%

3.3.1. b. ***Form of Application***

F1 - Fresh form

Fresh garlic and black pepper were crushed and curry leaves and coriander leaves were chopped and squeezed

F2 - Oven dried powdered form

Total no. of treatments	-	4
Replication	-	4
Design	-	CRD

3.3.2. Preliminary Evaluation of Sensory Quality Parameters

The prepared chips were organoleptically evaluated using a 9 point hedonic scale (Appendix II) by a 30 member semi trained panel. The panel was asked to rank the flavoured chips. The chips having maximum score was identified from each type of flavour imparting substance.

3.3.3. Selection of Flavoured Chips

Flavoured chips were prepared using the best treatments selected from preliminary study (3.3.2) and compared by evaluating their sensory quality attributes to select the best flavoured chips. The panel were asked to score the appearance, colour, flavour, taste, crispiness and overall acceptability of the sample using a specially designed score card (Appendix III).

3.4. COST OF PRODUCTION

Cost of production of 1 kg banana chips prepared using the selected antioxidant, was calculated as per the current market rate (Appendix IV).

3.5. STATISTICAL ANALYSIS

The treatment combinations were grouped according to the form, concentration and method of application of antioxidants and analyzed using one way ANOVA and significance was tested using CD. In organoleptic analysis, the different preferences as indicated by scores were evaluated by Kruskall – Wallis test to get the mean rank values for all the treatments.

Results

4. RESULTS

The experimental data collected from the investigation on "Development of Nendran Banana Chips with Enhanced Shelf Life and Quality" were analyzed and the results are presented in this chapter in three headings.

4.1. Effect of antioxidants on quality of banana chips

4.2. Storage potential of treated banana chips

4.3. Development of flavoured banana chips

4.1. EFFECT OF ANTIOXIDANTS ON QUALITY OF BANANA CHIPS

4.1.1. Preparation of Banana Chips with the Incorporation of Antioxidants

Nendran banana chips were prepared by incorporating two set of antioxidants viz. processing waste and flavour imparting substances in two different forms viz. fresh and oven dried powdered form by two different methods viz., presoaking slices in antioxidants before frying and direct addition of antioxidants in oil. Two experiments with 32 treatments each, were conducted separately with 2 set of antioxidants.

4.1.2. Effect of Processing Waste in Controlling Rancidity of Banana Chips

Four different processing wastes rich in antioxidants viz., banana peel, potato peel, watermelon peel and cucumber peel were incorporated in Nendran banana chips prepared in unrefined coconut oil.

4.1.2.a. *Effect of Processing Waste on Physical Quality of Banana Chips*

Banana chips produced by the incorporation of processing waste containing antioxidants showed significant difference in physical quality parameters like, yield, moisture content, oil uptake, integrity and shrinkage (Table 1.).

Table 1. Physical quality parameters of banana chips prepared with the incorporation of processing waste.

Treatments	Yield (%)	Moisture (%)	Oil uptake(%)	Integrity (%)	Shrinkage (%)
A1F1C1M1	70.70	7.95	35.80	82.95	22.85
A1F1C2M1	71.70	7.40	37.00	82.75	22.75
A1F1C1M2	66.10	7.05	33.10	84.00	21.45
A1F1C2M2	65.60	6.45	30.65	84.45	21.00
A1F2C1M1	72.30	8.70	37.10	82.90	23.00
A1F2C2M1	77.10	9.00	38.05	81.80	22.50
A1F2C1M2	66.80	6.90	32.10	84.60	21.05
A1F2C2M2	64.60	6.70	30.70	84.15	20.80
A2F1C1M1	71.80	7.35	37.10	80.90	22.85
A2F1C2M1	72.40	8.40	37.70	81.20	23.10
A2F1C1M2	67.70	6.65	34.40	83.05	21.50
A2F1C2M2	65.80	6.90	31.55	83.15	20.95
A2F2C1M1	70.30	8.50	37.90	83.20	22.95
A2F2C2M1	73.80	8.75	39.77	81.75	22.10
A2F2C1M2	66.10	7.25	34.30	84.05	21.75
A2F2C2M2	66.90	6.90	33.85	82.25	21.40
A3F1C1M1	71.80	7.50	36.05	81.90	23.05
A3F1C2M1	70.20	8.15	36.70	79.70	23.15
A3F1C1M2	64.60	7.00	33.10	81.85	22.00
A3F1C2M2	63.00	6.35	32.85	80.60	21.55
A3F2C1M1	70.30	8.95	39.30	80.90	22.90
A3F2C2M1	71.20	8.00	38.20	81.90	22.45
A3F2C1M2	67.00	7.20	32.85	82.55	21.60
A3F2C2M2	65.80	7.30	34.00	82.00	21.40
A4F1C1M1	70.20	8.25	41.75	80.75	23.10
A4F1C2M1	71.00	7.45	38.20	82.45	23.25
A4F1C1M2	67.40	7.70	32.80	82.00	21.75
A4F1C2M2	69.70	7.30	33.60	80.90	22.40
A4F2C1M1	70.10	9.00	36.95	80.35	22.90
A4F2C2M1	71.80	8.40	38.25	80.65	22.65
A4F2C1M2	66.70	7.55	33.20	81.00	21.75
A4F2C2M2	62.10	7.40	31.85	82.05	21.25
CD (P=0.05)	5.27	0.84	1.98	1.57	0.85

4.1.2.a.1. ***Yield***

Banana chips prepared from slices presoaked in 0.02% oven dried banana peel powder (A1F2C2M1) recorded the highest yield recovery (77.10%) which was on par with A2F2C2M1 (73.80%), A2F1C2M1 (72.40%), A1F2C1M1 (72.30%), A2F1C1M1 (71.80%), A3F1C1M1 (71.80%) and A4F2C2M1 (71.80%). Banana chips prepared by directly adding 0.02% oven dried cucumber peel powder (A4F2C2M2) recorded the lowest yield recovery (62.10%) which was on par with A3F1C2M2 (63.00%), A1F2C2M2 (64.60%), A3F1C1M2 (64.60), A1F1C2M2 (65.60%), A2F1C2M2 (65.80%), A3F2C2M2 (65.80%), A2F2C1M2 (66.10%), A1F1C1M2 (66.10%), A4F2C1M2 (66.70%), A1F2C1M2 (66.80%), A2F2C2M2 (66.90%) and A3F2C1M2 (67.00%).

4.1.2.a.2. ***Moisture Content (%)***

Fresh watermelon peel applied directly to frying oil at 0.02% concentration (A3F1C2M2) recorded the lowest moisture content (6.35%) which was on par with A1F1C2M2 (6.45%), A2F1C1M2 (6.65%), A1F2C2M2 (6.70%), A1F2C1M2 (6.90%), A2F1C2M2 (6.90%), A2F2C2M2 (6.90%), A3F1C1M2 (7.00%) and A1F1C1M2 (7.05%).

A higher moisture content of 9.00% was recorded by slices presoaked in 0.02% oven dried banana peel powder (A1F2C2M1) and slices presoaked with oven dried cucumber peel powder applied at 0.01% concentration (A4F2C1M1) which were on par with A3F2C1M1 (8.95%), A2F2C2M1 (8.75%), A1F2C1M1 (8.70%), A2F2C1M1 (8.50%), A2F1C2M1 (8.40%), A4F2C2M1 (8.40%) and A4F1C1M1 (8.25%).

4.1.2.a.3. ***Oil Uptake (%)***

Fresh banana peel applied directly to frying oil at 0.02% concentration (A1F1C2M2) recorded the lowest oil uptake (30.65%) which was on par with oven dried watermelon peel powder applied directly to frying oil at 0.02% concentration (A1F2C2M2) (30.70%), A2F1C2M2 (31.55%), A4F2C2M2 (31.85%) & A1F2C1M2 (32.10%). Slices presoaked in 0.01% fresh cucumber peel recorded significantly the highest oil uptake (41.75%) which was on par with A2F2C2M1 (39.77%) (Plate 11).

4.1.2.a.4. ***Integrity***

The highest integrity was recorded by chips prepared with the addition of 0.01% oven dried banana peel powder to frying oil (A1F2C1M2) (84.60%) which was on par with A1F1C2M2 (84.45%), A1F2C2M2 (84.15%), A2F2C1M2 (84.05%), A1F1C1M2 (84.00%), A2F2C1M1 (83.20%), A2F1C2M2 (83.15%) and A2F1C1M2 (83.05%).

The lowest integrity (79.70%) was recorded by chips prepared from slices presoaked in 0.02% solution of fresh watermelon peel (A3F1C2M1) which was on par with A4F2C1M1 (80.35%), A3F1C2M2 (80.60%), A4F2C2M1 (80.65%), A4F1C1M1 (80.70%), A2F1C1M1 (80.90%), A3F2C1M1 (80.90%), A4F1C2M2 (80.90%), A4F2C1M2 (81.00%) and A2F1C2M1 (81.20%).

4.1.2.a.5. ***Shrinkage***

Least shrinkage was observed by chips prepared with direct addition of 0.02% oven dried banana peel powder into frying oil (A1F2C2M2) (20.80%), which was on par with A2F1C2M2 (20.95%), A1F1C2M2 (21.00%), A1F2C1M2 (21.05%), A4F2C2M2 (21.25%), A2F2C2M2 (21.40%), A3F2C2M2 (21.40%), A1F1C1M2 (21.45%), A2F1C1M2 (21.50%), A3F1C2M2 (21.55%), and A3F2C1M2 (21.60%).

The highest shrinkage (23.25%) was recorded by chips prepared from slices presoaked in 0.02% fresh cucumber peel solution which was on par with A3F1C2M1 (23.15%), A2F1C2M1 (23.10%), A4F1C1M1 (23.10%), A3F1C1M1 (23.05%), A1F2C1M1 (23.00%), A2F2C1M1 (22.95%), A4F2C1M1 (22.90%), A3F2C1M1 (22.90%), A1F1C1M1 (22.85%), A2F1C1M1 (22.85%), A1F1C2M1 (22.75%), A1F2C2M1 (22.75%), A4F2C2M1 (22.65%), A1F2C2M1 (22.50%), A3F2C2M1 (22.45%) and A4F1C2M2 (22.40%).

4.1.2.b. *Effect of Processing Waste on Chemical Quality of Banana Chips*

Banana chips produced by the incorporation of antioxidant rich processing waste showed significant difference in chemical quality parameters viz., Free fatty acid value (mg KOH/g), Peroxide value (meq. O_2 / kg) and Iodine value (Table.2.) at three months of storage.

4.1.2.b.1. *Free Fatty Acid Value (FFA Value)*

When the effect of processing waste on free fatty acid value of banana chips was studied, the lowest FFA value (3.08 mg KOH/g) and (3.37 mg KOH/g) was recorded by chips prepared after adding fresh banana peel directly to frying oil at 0.02% and 0.01% concentration respectively, at three months of storage.

The highest FFA value was recorded by chips prepared from slices presoaked in 0.01% oven dried cucumber peel powder (A4F2C1M1) (12.34 mg KOH/g) which was on par with A2F2C2M1 (12.06 mg KOH/g), A2F2C1M1 (11.78 mg KOH/g), A3F2C2M1 (11.78 mg KOH/g), A4F1C2M1 (11.78 mg KOH/g), A4F2C2M1 (11.78 mg KOH/g) and A4F1C1M1 (11.22 mg KOH/g).

4.1.2.b.2. *Peroxide Value*

When the effect of antioxidant rich processing waste on the peroxide value of banana chips was studied, the lowest value of 4.70 meq. O_2 / Kg was recorded by chips prepared after adding fresh banana peel directly to frying oil at 0.01% and 0.02% concentration. This was on par with chips prepared by adding oven dried banana peel powder directly to frying oil at 0.01% (5.00 meq. O_2 / Kg) and at 0.02% concentration (5.10 meq. O_2 / Kg).

Chips prepared with slices presoaked in 0.02% oven dried watermelon peel powder (A3F2C2M1) recorded the highest peroxide value (9.40 meq. O_2 / Kg) which was on par with A3F2C1M1, A4F1C1M1 and A4F1C2M1 (9.30 meq. O_2/ kg), A3F1C2M1 (9.10 meq. O_2 / Kg) and A3F1C1M1 (9.00 meq. O_2 / Kg).

Table 2. Chemical quality parameters of banana chips prepared with the incorporation of processing waste

Treatments	Free fatty acid value (mg KOH/g)	Peroxide value (meq. O_2/kg)	Iodine value
A1F1C1M1	5.05	6.20	7.54
A1F1C2M1	5.33	6.10	7.75
A1F1C1M2	3.37	4.70	8.68
A1F1C2M2	3.08	4.70	8.76
A1F2C1M1	9.26	7.00	6.69
A1F2C2M1	8.71	6.80	6.79
A1F2C1M2	6.17	5.00	5.96
A1F2C2M2	6.70	5.10	6.22
A2F1C1M1	10.38	7.40	5.78
A2F1C2M1	11.22	7.50	6.67
A2F1C1M2	9.54	6.40	6.73
A2F1C2M2	9.54	6.50	7.05
A2F2C1M1	11.78	7.40	6.47
A2F2C2M1	12.06	7.30	6.60
A2F2C1M2	9.26	6.40	7.24
A2F2C2M2	9.53	6.10	7.42
A3F1C1M1	10.43	9.00	6.41
A3F1C2M1	10.37	9.10	6.67
A3F1C1M2	8.14	6.50	7.49
A3F1C2M2	8.97	6.10	7.61
A3F2C1M1	10.43	9.30	6.22
A3F2C2M1	11.78	9.40	6.67
A3F2C1M2	9.26	6.70	7.36
A3F2C2M2	9.26	7.10	7.43
A4F1C1M1	11.22	9.30	6.28
A4F1C2M1	11.78	9.30	6.79
A4F1C1M2	8.42	8.50	7.61
A4F1C2M2	9.26	8.80	7.68
A4F2C1M1	12.34	8.40	6.16
A4F2C2M1	11.78	8.80	6.35
A4F2C1M2	9.26	7.40	7.42
A4F2C2M2	9.26	7.60	7.74
CD (P=0.05)	1.30	0.50	0. 52

4.1.2.b.3. *Iodine Value*

When the effect of processing waste on the iodine value of banana chips was recorded the highest value of 8.76 and 8.68 was observed by chips prepared after adding fresh banana peel directly to frying oil at 0.02% and 0.01% concentration respectively.

The lowest iodine value (5.78) was recorded by chips prepared by using slices presoaked in 0.01% fresh potato peel which was on par with A1F2C1M2 (5.96), A4F2C1M1 (6.16), A1F2C2M2 and A3F2C1M1 (6.22) and A4F1C1M1 (6.28).

4.1.2.c. *Effect of Processing Waste on Sensory Quality of Banana Chips*

Banana chips produced by the incorporation of antioxidant rich processing waste showed significant difference in sensory quality parameters like, appearance, colour, flavor, taste, texture and overall acceptability (Table 3.).

4.1.2.c.1. *Appearance*

The highest mean rank value for appearance (220.00) was recorded by banana chips prepared after adding 0.02% fresh and oven dried banana peel directly to frying oil.

The lowest mean rank value for appearance (77.25) was recorded by banana chips prepared from slices presoaked in 0.02% concentration of fresh water melon peel (A3F1C2M1).

4.1.2.c.2. *Colour*

The highest mean rank value for colour (223.50) was recorded by banana chips prepared after adding fresh banana peel or cucumber peel directly to frying oil at 0.02% concentration.

The lowest mean rank value for colour (75.80) was recorded by banana chips prepared using slices presoaked in 0.01% concentration of oven dried watermelon peel powder (A3F2C1M1).

Table 3. Sensory quality parameters of banana chips prepared with the incorporation of processing waste.

Treatments	Mean Rank Values					
	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability
A1F1C1M1	160.00	174.60	163.20	154.70	167.25	187.00
A1F1C2M1	220.00	203.40	189.80	168.55	167.25	173.10
A1F1C1M2	153.90	139.60	124.70	163.10	159.80	145.30
A1F1C2M2	220.00	223.50	209.80	266.90	248.80	268.10
A1F2C1M1	130.00	149.90	148.50	196.25	102.80	149.00
A1F2C2M1	130.00	154.00	133.80	210.10	170.65	206.70
A1F2C1M2	190.00	203.40	182.60	212.50	215.15	242.60
A1F2C2M2	220.00	209.10	175.10	261.45	243.65	246.10
A2F1C1M1	138.90	174.60	193.90	157.50	131.30	159.20
A2F1C2M1	134.45	143.70	148.50	143.65	142.15	145.30
A2F1C1M2	205.00	174.60	219.20	196.25	181.50	200.90
A2F1C2M2	190.00	174.60	189.80	182.40	181.50	200.90
A2F2C1M1	134.45	145.80	160.40	140.85	109.60	100.80
A2F2C2M1	134.45	174.60	121.90	143.65	120.45	100.80
A2F2C1M2	205.00	174.60	133.80	143.65	142.15	206.70
A2F2C2M2	190.00	189.00	175.10	196.25	167.25	220.60
A3F1C1M1	134.45	149.90	160.40	143.65	117.05	86.90
A3F1C2M1	77.25	135.00	148.50	93.85	120.45	86.90
A3F1C1M2	149.45	149.90	175.10	148.55	167.25	149.00
A3F1C2M2	160.00	174.10	179.20	176.25	181.50	173.10
A3F2C1M1	119.45	75.80	107.20	107.70	117.05	86.90
A3F2C2M1	145.00	96.40	148.50	93.85	156.40	86.90
A3F2C1M2	149.45	117.00	175.10	146.45	156.40	121.20
A3F2C2M2	175.00	174.60	160.40	168.55	181.50	159.20
A4F1C1M1	135.45	125.20	175.10	143.65	142.15	135.10
A4F1C2M1	175.00	174.60	175.10	154.70	195.75	173.10
A4F1C1M2	190.00	174.60	175.10	143.65	156.40	138.80
A4F1C2M2	210.45	223.50	208.60	173.45	195.75	187.00
A4F2C1M1	134.45	149.90	95.30	82.80	145.55	100.80
A4F2C2M1	119.45	121.100	83.40	82.80	142.15	114.70
A4F2C1M2	130.00	149.90	148.50	143.65	156.40	184.70
A4F2C2M2	175.00	135.50	160.40	154.70	153.00	198.60
CV	81.10					

4.1.2.c.3. *Flavour*

The highest mean rank value for flavour (219.20) was recorded by banana chips prepared after adding 0.01% fresh potato peel directly to frying oil (A2F1C1M2).

The lowest mean rank value for flavour (83.40) was recorded by banana chips prepared from slices presoaked in 0.02% oven dried cucumber peel powder (A4F2C2M1).

4.1.2.c.4. *Taste*

The highest mean rank value for taste (266.90) was recorded by banana chips prepared after adding 0.02% of fresh banana peel directly to frying oil (A1F1C2M2).

The lowest mean rank value for taste (82.80) was recorded by banana chips prepared from slices presoaked in 0.01% or 0.02% concentration of oven dried cucumber peel powder.

4.1.2.c.5. *Texture*

The highest mean rank value for texture (248.80) was recorded by banana chips prepared after adding fresh banana peel directly to frying oil at 0.02% concentration (A1F1C2M2).

The lowest mean rank value for texture (102.80) was recorded by banana chips prepared using slices presoaked in 0.01% oven dried banana peel powder (A1F2C1M1).

4.1.2.c.6. *Overall Acceptability*

The highest mean rank value for overall acceptability (268.10) was recorded by banana chips prepared after adding 0.02% fresh banana peel directly to frying oil (A1F1C2M2).

The lowest mean rank value for overall acceptability (86.90) was recorded by banana chips prepared using slices presoaked in 0.01% or 0.02% fresh water melon peel and oven dried watermelon peel powder.

4.1.3. Effect of Flavour Imparting Substances in Controlling Rancidity of Banana Chips

Nendran banana chips were prepared in unrefined coconut oil by addition of four antioxidant rich flavour imparting substances viz., garlic, black pepper, curry leaf and coriander leaves. The treated chips were evaluated for their physical, chemical and sensory quality parameters.

4.1.3.a. *Effect of Flavour Imparting Substances on Physical Quality of Banana Chips*

Banana chips produced by the incorporation of flavour imparting substances showed significant difference in physical quality parameters like, yield, moisture content (%), oil uptake (%), integrity and shrinkage (Table 4.).

4.1.3.a.1. *Yield*

Chips prepared from slices presoaked in 0.01% fresh garlic had the highest yield recovery (A5F1C1M1) (75.40%) which was on par with A5F1C2M1 (74.35%), A6F1C1M1 (72.40%), A5F2C2M1 (72.20%), A7F1C1M1 (72.15%), A6F1C2M1 and A8F1C1M1 (71.70%), A7F1C2M1 (71.45%), A6F2C1M1 (71.00%), A6F2C2M1 (70.70%), A5F2C1M1 and A8F1C2M1 (70.50%), A7F1C1M2 (69.95%) and A8F2C1M1 (69.85%).

Chips prepared after adding 0.02% oven dried curry leaf powder to frying oil (A7F2C2M2) recorded the lowest yield recovery (64.15%) which was on par with A8F2C2M2 (65.00%), A5F2C2M2 (65.15%), A7F2C1M2 (65.30%), A5F1C2M2 (65.80%), A8F2C1M2 (66.00%), A6F2C1M2 (66.05%), A5F2C1M2 (66.40%), A8F1C1M2 (66.65%), A5F1C1M2 (66.80%), A6F2C2M2 (67.00%), A7F2C1M1 (67.80%), A6F1C2M2 (68.10%), A8F1C2M2 (68.20%), A6F1C1M2 (68.50%), A8F2C2M1 (68.80%), A7F1C2M2 (68.85%), A7F2C2M1 (68.90%), A8F2C1M1 (69.85%) and A7F1C1M2 (69.95%).

Table 4. Physical quality parameters of banana chips prepared with the incorporation of flavor imparting substances.

Treatments	Yield (%)	Moisture (%)	Oiluptake (%)	Integrity (%)	Shrinkage (%)
A5F1C1M1	75.40	8.25	40.20	82.05	23.30
A5F1C2M1	74.35	8.00	39.25	82.50	23.10
A5F1C1M2	66.80	6.65	37.05	80.50	22.55
A5F1C2M2	65.80	7.05	35.80	82.25	22.95
A5F2C1M1	70.50	6.30	39.25	82.90	22.20
A5F2C2M1	72.20	6.05	38.85	82.00	23.35
A5F2C1M2	66.40	5.55	34.40	84.50	22.50
A5F2C2M2	65.15	5.90	35.85	83.95	23.15
A6F1C1M1	72.40	7.50	38.95	82.90	22.90
A6F1C2M1	71.70	8.15	40.50	82.10	23.30
A6F1C1M2	68.50	6.50	35.60	82.75	22.65
A6F1C2M2	68.10	6.70	36.35	83.15	23.30
A6F2C1M1	71.00	7.35	37.40	83.20	22.65
A6F2C2M1	70.70	7.40	38.05	82.10	23.00
A6F2C1M2	66.05	6.90	34.85	84.05	22.25
A6F2C2M2	67.00	6.50	34.00	83.70	23.05
A7F1C1M1	72.15	7.50	37.45	82.25	23.25
A7F1C2M1	71.45	7.40	37.45	81.95	23.15
A7F1C1M2	69.95	5.95	35.95	83.90	21.85
A7F1C2M2	68.85	6.10	36.45	84.05	21.90
A7F2C1M1	67.80	6.20	38.50	82.65	23.30
A7F2C2M1	68.90	6.15	37.80	82.65	23.20
A7F2C1M2	65.30	5.50	33.80	84.75	22.35
A7F2C2M2	64.15	5.30	31.40	85.90	20.95
A8F1C1M1	71.70	7.50	38.70	82.85	23.30
A8F1C2M1	70.50	7.35	37.75	83.85	23.45
A8F1C1M2	66.65	6.40	36.35	83.70	23.25
A8F1C2M2	68.20	6.15	38.70	83.85	22.45
A8F2C1M1	69.85	6.25	42.05	82.85	23.30
A8F2C2M1	68.80	6.75	39.10	82.55	22.95
A8F2C1M2	66.00	5.65	33.05	84.85	21.90
A8F2C2M2	65.00	5.40	33.05	86.15	21.00
CD (P=0.05)	6.21	1.05	2.72	1.62	0.82

4.1.3.a.2. *Moisture Content (%)*

Chips prepared by adding oven dried curry leaf powder directly to frying oil at 0.02% concentration (A7F2C2M2) recorded the least moisture content (5.30%) which was on par with A8F2C2M2 (5.40%), A7F2C1M2 (5.50%), A5F2C1M2 (5.55%), A8F2C1M2 (5.65%), A5F2C2M2 (5.90%), A7F1C1M2 (5.95%), A5F2C2M1 (6.05%), A7F1C2M2 (6.1%), A7F2C2M1 and A8F1C2M2 (6.15%), A7F2C1M1 (6.2%), A8F2C1M1 (6.25%) and A5F2C1M1 (6.30%).

Chips prepared from slices presoaked in 0.01% fresh garlic paste (A5F1C1M1) recorded the highest moisture content (8.25%) which was on par with A6F1C2M2 (8.15%), A5F1C2M1 (8.00%), A6F1C1M1, A7F1C1M1 and A8F1C1M1 (7.50%), A6F2C2M1 and A7F1C2M1 (7.40%), A6F2C1M1 and A8F1C2M1 (7.35%).

4.1.3.a.3. *Oil Uptake (%)*

Chips prepared by adding oven dried curry leaf powder directly to frying oil at 0.02% concentration (A7F2C2M2) recorded the least oil uptake (31.40%) which was on par withA8F2C2M2 and A8F2C1M2 (33.05%), A7F2C1M2 (33.80%) and A6F2C2M2 (34.00%).

Chips prepared using slices presoaked in 0.01% of oven dried coriander leaf powder (A8F2C1M2) recorded the highest oil uptake (42.05%) which was on par with A5F1C1M1 (40.20%) and A6F1C2M1 (40.50%).

4.1.3.a.4. *Integrity*

Highest integrity (86.15%) was shown by chips prepared after adding oven dried coriander leaf powder directly to frying oil at 0.02% concentration (A8F2C2M2) which was on par with A7F2C2M2 (85.90%), A8F2C1M2 (84.85%) and A7F2C1M2 (84.75%).

Chips prepared by applying fresh garlic directly to frying oil at 0.01% concentration (A8F2C2M2) recorded the least integrity (80.50%) which is on par with A7F1C2M1 (81.95%), A5F2C2M1 (82.00%), A5F1C1M1 (82.05%), A6F1C2M1 and A6F2C2M1 (82.10%).

4.1.3.a.5. *Shrinkage*

Least shrinkage (20.95%) was observed in chips prepared after adding 0.02% oven dried curry leaf powder directly to frying oil (A7F2C2M2) which was on par with chips prepared after adding oven dried coriander leaf powder directly to frying oil at 0.02% concentration (A8F2C2M2) (21.00%).

Chips prepared from slices presoaked in 0.02% fresh coriander leaf (A8F1C2M1) recorded the highest (23.45%) shrinkage which was on par with A5F2C2M1 (23.35%), A5F1C1M1, A6F1C2M1, A6F1C2M2, A7F2C1M1, A8F1C1M1 and A8F2C1M1 (23.30%), A7F1C1M1 and A8F1C1M2 (23.25%), A7F2C2M1 (23.2%), A5F2C2M2 and A7F1C2M1 (23.15%), A5F1C2M1 (23.10%), A6F2C2M2 (23.05%), A6F2C2M1 (23.00%), A5F1C2M2 and A8F2C2M1 (22.95%), A6F1C1M1 (22.90%), A6F1C1M2 and A6F2C1M1 (22.65%).

4.1.3.b. *Effect of Flavour Imparting Substances on Chemical Quality of Banana Chips*

Banana chips produced by the incorporation of flavor imparting substances containing antioxidants showed significant difference in chemical quality parameters like free fatty acid value (mg KOH/g), peroxide value (meq. O_2 / kg) and iodine value (Table 5.) at three months of storage.

4.1.3.b.1. *Free Fatty Acid Value*

When the effect of antioxidant rich flavour imparting substances on FFA value of banana chips was studied (Table 5.) the lowest FFA value (2.52 mg KOH/g) was noticed in chips prepared after adding 0.02% oven dried coriander leaf powder directly to frying oil (A8F2C2M2) which was on par with chips prepared after addition of oven dried curry leaf powder to frying oil at 0.02% concentration (3.02 mg KOH/g).

The highest FFA value (10.94 mg KOH/g) was recorded by chips prepared using slices presoaked in 0.02% of oven dried garlic powder (A7F2C2M1) which

Table 5. Chemical quality parameters of banana chips prepared with the incorporation of flavor imparting substances

Treatments	Free fatty acid value (mg KOH/g)	Peroxide value (meq. O_2/kg)	Iodine value
A5F1C1M1	8.98	8.50	3.32
A5F1C2M1	9.54	8.20	3.87
A5F1C1M2	7.02	8.20	4.60
A5F1C2M2	7.85	8.30	4.80
A5F2C1M1	9.54	7.70	4.19
A5F2C2M1	10.94	8.40	4.31
A5F2C1M2	7.58	8.00	4.73
A5F2C2M2	7.58	8.10	4.85
A6F1C1M1	10.12	8.50	4.31
A6F1C2M1	8.97	8.90	4.63
A6F1C1M2	7.30	8.40	5.77
A6F1C2M2	7.02	8.20	5.58
A6F2C1M1	10.12	8.10	4.73
A6F2C2M1	9.54	8.40	4.68
A6F2C1M2	7.58	8.10	5.78
A6F2C2M2	7.29	8.50	5.86
A7F1C1M1	10.40	8.40	4.49
A7F1C2M1	10.12	8.50	4.60
A7F1C1M2	7.30	8.30	5.52
A7F1C2M2	7.58	8.60	5.84
A7F2C1M1	9.25	8.30	4.31
A7F2C2M1	10.66	8.10	4.63
A7F2C1M2	7.30	7.90	5.52
A7F2C2M2	3.02	6.50	6.73
A8F1C1M1	10.09	8.20	3.75
A8F1C2M1	8.69	8.50	3.81
A8F1C1M2	7.85	7.80	5.78
A8F1C2M2	7.86	8.20	6.09
A8F2C1M1	10.10	9.30	4.12
A8F2C2M1	9.79	9.00	4.37
A8F2C1M2	7.24	7.70	5.52
A8F2C2M2	2.52	6.20	6.35
CD (P=0.05)	0.50	1.19	0.62

was on par with banana chips prepared from slices presoaked in 0.02% oven dried curry leaf powder (A7F2C2M1).

4.1.3.b.2. *Peroxide Value*

When the effect of antioxidant rich flavour imparting substances on peroxide value of banana chips was studied the lowest peroxide value (6.20 meq. O_2 / kg) was recorded by chips prepared after adding oven dried coriander leaf powder directly to frying oil at 0.02% concentration (A8F2C2M2) which was on par with chips prepared after adding oven dried curry leaf powder directly to frying oil at 0.02% concentration (6.50 meq. O_2 / kg) (Table 5.).

Chips prepared using slices presoaked in 0.01% oven dried coriander leaf powder (A8F2C1M1) recorded the highest peroxide value (9.30 meq. O_2 / kg) which was on par with A8F2C2M1 (9.00 meq. O_2 / kg), A6F1C2M1 (8.90 meq. O_2 / kg), A7F1C2M2 (8.60 meq. O_2 / kg), A5F1C1M1, A6F1C1M1, A6F2C2M2, A7F1C2M1 and A8F1C2M1 (8.50 meq. O_2 / kg), A5F2C2M1, A6F1C1M2, A6F2C2M1 and A7F1C1M1 (8.40 meq. O_2 / kg), A5F1C2M2, A7F1C1M2 and A7F2C1M1 (8.30 meq. O_2 / kg), A5F1C2M1, A5F1C1M2, A6F1C2M2, A8F1C1M1 and A8F1C2M2 (8.20 meq. O_2 / kg).

4.1.3.b.3. *Iodine Value*

When the effect of antioxidant rich flavour imparting substances on iodine value of banana chips was studied (Table 5) the highest value (6.73) was recorded by chips prepared by adding oven dried curry leaf powder directly to frying oil at 0.02% concentration (A7F2C2M2) which was on par with chips prepared by adding oven dried coriander leaf powder to frying oil at 0.02% concentration (6.35).

Chips prepared from slices presoaked in 0.01% of fresh garlic paste (A5F1C1M1) recorded the lowest iodine value (3.32) which was on par with A8F1C1M1 (3.75), A8F1C2M1 (3.81) and A5F1C2M1 (3.87).

4.1.3.c. *Effect of Flavour Imparting Substances on Sensory Quality of Chips*

Banana chips produced by the incorporation of antioxidant rich flavour imparting substances showed significant difference in sensory quality parameters like, appearance, colour, flavour, taste, texture and overall acceptability (Table 6.).

4.1.3.c.1. *Appearance*

The highest mean rank value for appearance (281.20) was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder to frying oil (A7F2C2M2) which was on par with chips prepared after adding 0.02% oven dried coriander leaf powder to frying oil (252.40).

Banana chips prepared from slices presoaked in 0.01% fresh (C7F1C1M1) and oven dried curry leaves powder (C7F2C1M1) as well as slices presoaked with 0.02% fresh coriander leaves (C8F1C2M1) recorded the lowest mean rank value for appearance (122.40).

4.1.3.c.2. *Colour*

The highest mean rank value for colour (278.25) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder directly to frying oil (A7F2C2M2) which was on par with chips prepared after adding 0.02% oven dried coriander leaf powder to frying oil (271.35).

The lowest mean rank value for colour (122.80) was recorded by banana chips prepared from slices presoaked in 0.01% fresh curry leaves (A6F1C1M1) and 0.02% oven dried black pepper powder (A7F1C1M1).

4.1.3.c.3. *Flavour*

The highest mean rank value for flavour (284.10) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder directly to frying oil (A7F2C2M2) which was on par with chips prepared after adding 0.02% oven dried coriander leaf powder applied directly to frying oil (248.25).

Table 6. Sensory quality parameters of banana chips prepared with the incorporation of flavour imparting substances.

Treatments	Mean Rank Value					
	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability
A5F1C1M1	136.90	126.20	151.40	144.70	162.50	128.30
A5F1C2M1	136.90	131.80	112.90	151.90	162.50	128.30
A5F1C1M2	181.80	176.90	166.25	166.25	177.60	175.25
A5F1C2M2	152.80	140.80	136.55	187.75	132.30	143.95
A5F2C1M1	132.00	131.80	127.75	128.85	147.40	128.30
A5F2C2M1	146.50	131.80	121.70	143.20	147.40	128.30
A5F2C1M2	151.40	170.00	164.45	180.55	162.50	175.25
A5F2C2M2	152.80	176.90	166.25	180.60	147.40	159.60
A6F1C1M1	127.30	131.80	151.40	128.85	162.50	143.95
A6F1C2M1	146.50	170.00	136.55	166.25	139.05	128.30
A6F1C1M2	157.70	155.40	173.25	166.25	162.50	159.60
A6F1C2M2	190.00	170.00	166.25	166.25	177.60	222.20
A6F2C1M1	146.50	122.80	151.40	134.50	123.95	112.65
A6F2C2M1	161.00	146.40	151.40	143.20	132.30	128.30
A6F2C1M2	167.30	162.30	173.25	180.55	162.50	206.55
A6F2C2M2	181.80	170.00	166.25	180.60	169.95	190.90
A7F1C1M1	122.40	122.80	151.40	114.50	139.05	128.30
A7F1C2M1	136.90	155.40	151.40	143.20	147.40	97.00
A7F1C1M2	146.50	162.30	173.25	159.05	162.50	175.25
A7F1C2M2	181.80	184.60	181.10	159.05	162.50	190.90
A7F2C1M1	122.40	131.80	127.75	128.85	147.40	128.30
A7F2C2M1	161.00	140.80	166.25	143.20	139.05	143.95
A7F2C1M2	175.50	176.90	180.25	151.90	169.95	159.60
A7F2C2M2	281.20	278.25	284.10	282.80	269.00	291.60
A8F1C1M1	136.90	146.40	142.60	143.20	147.40	143.95
A8F1C2M1	122.40	131.80	127.75	151.90	123.95	112.65
A8F1C1M2	181.80	170.00	181.10	173.40	154.85	175.25
A8F1C2M2	161.00	176.90	151.40	166.25	169.95	175.25
A8F2C1M1	141.80	155.40	142.60	120.15	162.50	175.25
A8F2C2M1	161.00	146.40	136.55	128.85	139.05	143.95
A8F2C1M2	181.80	170.00	173.25	173.40	169.95	175.25
A8F2C2M2	252.40	271.35	248.25	246.05	261.55	259.85
CV	81.10					

The lowest mean rank value for flavour (112.90) was recorded by banana chips prepared from slices presoaked in 0.02% fresh garlic (A5F1C2M1).

4.1.3.c.4. ***Taste***

The highest mean rank value for taste (282.80) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder to frying oil (A7F2C2M2) which was on par with chips prepared by adding 0.02% oven dried coriander leaf powder (246.05).

The lowest mean rank value for taste (114.50) was recorded by banana chips prepared from slices presoaked in 0.01% fresh curry leaves (A7F1C1M1) which was on par with all treatments except A7F2C2M2 and A8F2C2M2.

4.1.3.c.5. ***Texture***

The highest mean rank value for texture (269.00) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder directly to frying oil (A7F2C2M2) which was on par with chips prepared with 0.02% oven dried coriander leaf powder in frying oil (261.55).

The lowest mean rank value for texture (123.95) was recorded by banana chips prepared from slices presoaked in 0.02% oven dried black pepper powder (A6F2C1M1) and slices presoaked in 0.02% fresh coriander leaves (A8F1C2M1).

4.1.3.c.6. ***Overall Acceptability***

The highest mean rank value for overall acceptability (291.60) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder (A7F2C2M2) which was on par with chips prepared by adding 0.02% oven dried coriander leaf powder (A8F2C2M2) (259.85) and fresh black pepper (A6F2C1M2) directly to frying oil at 0.02% concentration.

The lowest mean rank value for overall acceptability (97.00) was recorded by banana chips prepared from slices presoaked in 0.02% fresh curry leaves (A7F1C2M1).

4.2. STORAGE POTENTIAL OF TREATED BANANA CHIPS

Storage stability and acceptability of banana chips prepared by adding 0.02% oven dried curry leaf powder and 0.02% fresh banana peel into frying oil were assessed by recording the physical, chemical and sensory quality parameters at periodic intervals.

4.2.1. Changes in Physical Quality

Physical parameters of treated chips viz., moisture, colour and texture were measured at regular intervals for a period of three months, after storing in three different packages/ packaging systems viz., LDPE pouch, laminated pouch and MAP in laminated pouch.

4.2.1. a. *Moisture Content*

All the treated banana chips packed in LDPE pouches had lower moisture content compared to untreated chips throughout the storage period of three months (Table 7.).

All the banana chips whether treated or not had similar moisture content when they were packaged in laminated pouches or under MAP system in laminated pouches. But from 15 days after storage onwards, antioxidant treated chips had lower moisture content compared to untreated chips.

Banana chips prepared after adding 0.02% oven dried curry leaf powder into frying oil had lowest moisture content (8.50%) which was on par with banana chips prepared by direct addition of 0.02% fresh banana peel (8.60%) at 90 days of storage in LDPE pouches. Control sample had a higher moisture content of 9.43% (Table 7.).

Among the samples packed in laminated pouches at 90 days of storage banana chips prepared by adding 0.02% oven dried curry leaf powder into frying oil recorded lowest moisture content of 7.33% which was on par with banana chips prepared by directly adding 0.02% fresh banana peel into frying oil (7.47%). Control sample recorded a higher moisture content of 8.90%.

When the samples are packed under MAP in laminated pouches banana chips prepared by directly adding 0.02% fresh banana peel into frying oil had lowest moisture content (6.83%) which was on par with banana chips prepared by directly adding 0.02% curry leaf powder into frying oil (6.90%) at 90 days of storage. Control samples recorded a higher moisture content (8.56%).

Among the three packaging systems, banana chips prepared by direct addition of 0.02% fresh banana peel or oven dried curry leaf powder into the frying oil and packaged under MAP in laminated pouches recorded the lowest moisture content of 6.83% and 6.90% respectively at 90 days of storage. Highest moisture content was recorded by untreated chips packed in LDPE (9.4%) which was followed by untreated chips in laminated pouches (8.90%) (Table 7.).

4.2.1. b. ***Yellowness Index (Colour)***

Colour, as yellowness index, of banana chips prepared by adding selected antioxidants and untreated samples stored under different packaging systems are shown in Table. 8.

There was no significant difference in colour of chips stored in any of the packaging material till 30 days of storage.

The samples packed in LDPE pouches had similar yellowness index throughout storage. However, highest yellowness index was recorded for banana chips prepared by directly adding 0.02% oven dried curry leaf powder (101.16).

When samples were stored in laminated pouches, highest yellowness index was recorded on 60 days of storage by banana chips prepared by adding 0.02% fresh banana peel (104.96) which was on par with 0.02% oven dried curry leaf powder treated chips (104.76). But treated and untreated chips had similar colour at 90 days of storage.

Among samples kept under MAP in laminated pouches, banana chips prepared by adding 0.02% oven dried curry leaf powder recorded highest

Table 7. Moisture content of chips during storage in different packaging materials

Treatments	MOISTURE CONTENT (%)						
	Days after storage						
	Initial	15	30	45	60	75	90
	LDPE						
Fresh banana peel	5.76	6.27	6.77	7.30	7.77	8.10	8.60
Curry leaf powder	5.50	6.00	6.63	7.23	7.77	8.17	8.50
Control	5.66	7.17	7.67	8.13	8.73	9.13	9.43
	Laminated pouch						
Fresh banana peel	5.93	6.23	6.43	6.73	7.00	7.23	7.47
Curry leaf powder	5.67	6.00	6.33	6.50	6.87	7.06	7.33
Control	5.76	7.27	7.70	8.07	8.33	8.70	8.90
	MAP						
Fresh banana peel	5.93	6.20	6.30	6.50	6.60	6.77	6.83
Curry leaf powder	5.77	6.00	6.20	6.43	6.60	6.70	6.90
Control	5.66	7.13	7.40	7.70	7.93	8.33	8.57
CD (P=0.05)	0.28	0.30	0.32	0.32	0.27	0.31	0.31

Table 8. Colour of chips during storage in different packaging materials

Treatments	Yellowness Index			
	Days after storage			
	Initial	30	60	90
	LDPE			
Fresh banana peel	111.22	107.99	102.64	98.78
Curry leaf powder	109.30	107.42	102.54	101.16
Control	112.64	104.92	100.10	98.43
	Laminated pouch			
Fresh banana peel	113.81	108.64	104.96	102.24
Curry leaf powder	114.04	108.36	104.76	100.57
Control	108.91	108.64	98.96	99.60
	MAP			
Fresh banana peel	108.24	108.80	108.89	108.54
Curry leaf powder	109.53	108.78	109.98	109.86
Control	111.56	107.25	103.89	100.96
CD (P=0.05)	NS	NS	4.24	4.11

Yellowness index (109.86) which was on par with 0.02% fresh banana peel treated chips (108.54). Untreated samples recorded least yellowness index (100.96) at 90 days of storage.

Among the three packaging systems tried, banana chips prepared by directly adding 0.02% oven dried curry leaf powder into frying oil and stored under MAP in laminated pouches recorded highest yellowness index (109.86) which was on par with 0.02% fresh banana peel treated chips packed under same system (108.54). Untreated samples packed in LDPE pouches recorded the least yellowness index (98.43) which was on par with all other samples stored under MAP in laminated pouches.

4.2.1. c. ***Textural Quality***

Texture, as measured by hardness, toughness and crispness of banana chips prepared by adding selected antioxidants and untreated samples during storage under different packaging systems are shown in Table. 9.

Among the samples packed in LDPE pouches, chips prepared by directly adding 0.02% oven dried curry leaf powder into frying oil recorded lowest hardness (5.15N) at 90 days of storage which was on par with 0.02% fresh banana peel treated chips (5.51N) and untreated samples (5.23N).

When samples are packed in laminated pouches, chips prepared by directly adding 0.02% oven dried curry leaf powder into frying oil recorded lowest hardness (5.65N) at 90 days of storage which was on par with 0.02% fresh banana peel treated chips (5.78N) and untreated samples (6.28N).

When the samples are stored under MAP in laminated pouches, banana chips prepared after adding 0.02% oven dried curry leaf powder recorded the lowest hardness (4.86N) at 90 days of storage which was on par with 0.02% fresh banana peel treated samples (5.96N).

When all the three packaging systems tried are compared together at 90 days of storage, least hardness was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder and stored under MAP in

Table 9. Texture of antioxidant treated chips during 3 months of storage in different packaging materials

Treatments	TEXTURE											
	Hardness [Force (N)]				Toughness [Area (Ns)]				Crispness [Count]			
	Initial	30	60	90	Initial	30	60	90	Initial	30	60	90
	LDPE											
Fresh banana peel	8.54	7.28	6.50	5.51	4.04	3.38	3.21	2.56	3.41	2.72	2.34	3.19
Curry leaf powder	8.89	6.82	6.20	5.15	4.86	3.12	3.23	3.42	3.83	3.49	3.16	2.37
Control	8.42	6.34	7.68	5.23	4.42	3.27	4.84	4.64	3.67	3.56	2.51	3.19
	Laminated pouch											
Fresh banana peel	7.87	7.40	6.85	5.78	3.69	3.82	3.20	2.73	3.83	3.56	2.70	2.88
Curry leaf powder	8.32	7.23	6.73	5.65	5.12	4.20	2.90	2.56	3.89	3.75	2.51	3.40
Control	8.25	8.08	6.75	6.28	4.15	2.96	3.63	2.73	3.58	3.63	3.16	2.96
	MAP											
Fresh banana peel	7.38	7.89	7.05	5.96	4.01	5.46	4.04	3.20	3.82	3.56	4.31	4.10
Curry leaf powder	8.42	6.82	6.17	4.86	4.03	5.26	2.42	1.90	4.61	4.54	5.32	5.12
Control	8.45	7.13	8.25	7.69	4.50	3.27	3.11	2.53	4.15	3.55	3.54	3.61
CD (P=0.05)	NS	1.06	0.68	1.43	0.76	1.36	NS	NS	NS	NS	1.12	0.73

laminated pouches (4.86N) which was on par with all other treatments except the untreated samples stored under MAP in laminated pouches (7.69N).

No significant difference existed between treated and untreated samples stored in different packaging materials at 60 and 90 days of storage in terms of toughness.

There was no significant difference in crispness between the chips stored in different packaging materials till 30 days of storage. Among the samples packed in LDPE pouches, banana chips prepared by addition of 0.02% fresh banana peel into frying oil and untreated samples recorded highest crispness (3.19) at 90 days of storage. Banana chips prepared by directly adding 0.02% oven dried curry leaf powder recorded the least crispness (2.37).

When samples are packed in laminated pouches, banana chips prepared after adding 0.02% oven dried curry leaf powder into frying oil recorded highest crispness (3.20) at 90 days of storage which was on par with 0.02% fresh banana peel treated (2.88) and untreated samples (2.96).

Among the samples stored under MAP in laminated pouches, banana chips prepared after adding 0.02% oven dried curry leaf powder into frying oil recorded the highest crispness (5.12) at 90 days of storage. Lowest crispness was recorded by untreated samples (3.61) which was on par with 0.02% fresh banana peel treated samples (4.10).

Among the three packaging systems tried, a significantly highest value for crispness (5.12) was recorded at 90 days of storage by banana chips prepared after adding 0.02% oven dried curry leaf powder into frying oil and stored under MAP in laminated pouches. Lowest crispness (2.37) was recorded by 0.02% oven dried curry leaf powder treated chips packed in LDPE pouches which was on par with 0.02% fresh banana peel treated chips (2.88) and untreated samples packed in laminated pouches (2.96).

4.2.2. Changes in Chemical Quality

Free fatty acid value, peroxide value, iodine value and total antioxidant activity of the stored chips varied significantly.

4.2.2. a. ***Free Fatty Acid Value***

Among the samples packed in LDPE pouches, banana chips prepared by directly adding 0.02% fresh banana peel into frying oil recorded lowest free fatty acid value (10.10 mg KOH/g) which was on par with banana chips prepared by direct addition of 0.02% oven dried curry leaf powder (10.66 mg KOH/g) at 90 days of storage. Control sample recorded a higher free fatty acid value (11.22 mg KOH/g) which was on par with banana chips prepared by directly adding 0.02% of oven dried curry leaf powder into frying oil (10.66 mg KOH/g).

When samples are packed in laminated pouches, banana chips prepared by directly adding 0.02% oven dried curry leaf powder into frying oil recorded lowest free fatty acid value of 6.92 mg KOH/g at 90 days of storage which was on par with banana chips prepared by directly adding 0.02% fresh banana peel into frying oil (7.11 mg KOH/g). Control sample recorded a higher free fatty acid value of 8.78 mg KOH/g.

Among the samples stored under MAP in laminated pouches, banana chips prepared after directly adding 0.02% oven dried curry leaf powder into frying oil recorded lowest free fatty acid value of 5.24 mg KOH/g at 90 days of storage which was on par with banana chips prepared by adding 0.02% fresh banana peel into frying oil (5.79 mg KOH/g). Control sample recorded a higher free fatty acid value of 7.48 mg KOH/g.

Among the three packaging systems tried, banana chips prepared by directly adding 0.02% oven dried curry leaf powder or fresh banana peel into the frying oil and packaged under MAP in laminated pouches recorded lowest free fatty acid values 5.24 mg KOH/g and 5.79 mg KOH/g respectively. Highest free fatty acid value was recorded by untreated chips packaged in LDPE (11.22 mg KOH/g) which was on par with banana chips prepared by directly adding 0.02% curry leaf powder into frying oil and packaged in the same condition (10.66 mg KOH/g) (Table 10.).

Table 10. Free fatty acid value of chips during storage in different packaging materials

Treatments	FREE FATTY ACID VALUE (mg KOH/g)						
	Days after storage						
	Initial	15	30	45	60	75	90
	LDPE						
Fresh banana peel	0.75	2.05	3.55	5.42	7.11	9.16	10.10
Curry leaf powder	1.12	1.68	3.93	5.60	7.11	9.16	10.66
Control	0.94	1.50	2.98	5.05	7.85	10.28	11.22
	Laminated pouch						
Fresh banana peel	0.94	1.87	3.17	4.30	4.86	5.79	7.11
Curry leaf powder	1.12	2.05	2.98	4.10	5.24	5.98	6.92
Control	0.75	1.87	2.80	3.74	5.43	7.11	8.78
	MAP						
Fresh banana peel	0.94	1.12	1.87	2.80	3.55	4.67	5.79
Curry leaf powder	0.56	1.31	2.24	2.98	3.74	4.48	5.24
Control	0.75	1.50	2.43	3.93	5.05	6.36	7.48
CD (P=0.05)	0.55	0.58	0.56	0.52	0.74	0.61	0.72

Table 11. Peroxide value of chips during storage in different packaging materials

Treatments	PEROXIDE VALUE (meq. O_2/kg)						
	Days after storage						
	Initial	15	30	45	60	75	90
	LDPE						
Fresh banana peel	4.40	5.33	6.27	7.33	8.47	9.20	10.00
Curry leaf powder	3.93	4.53	6.00	7.47	8.20	9.20	10.00
Control	6.27	6.87	7.40	8.33	9.40	11.47	12.80
	Laminated pouch						
Fresh banana peel	4.07	4.93	5.67	6.40	7.33	8.27	9.47
Curry leaf powder	4.00	4.53	5.20	6.00	7.07	7.53	8.27
Control	6.47	6.87	7.67	8.60	9.53	10.73	11.60
	MAP						
Fresh banana peel	4.73	5.33	5.80	6.53	7.07	7.47	8.13
Curry leaf powder	3.93	4.53	5.60	6.33	6.87	7.40	7.87
Control	6.47	6.87	7.40	7.80	8.33	8.80	9.33
CD (P=0.05)	0.37	0.30	0.40	0.35	0.35	0.29	0.27

4.2.2. b. *Peroxide Value*

Among the samples packed in LDPE pouches, a lower peroxide value of 10.00 meq. O_2/kg was recorded by banana chips prepared by directly adding 0.02% fresh banana peel and 0.02% of oven dried curry leaf powder at 90 days of storage. Control sample recorded the highest free fatty acid value of 12.80 meq. O_2/kg.

When packaging was done in laminated pouches, banana chips prepared by directly adding 0.02% curry leaf powder into frying oil recorded a lower peroxide value (8.27 meq. O_2/kg). Control sample recorded a higher peroxide value (11.60 meq. O_2/kg) at 90 days of storage.

Among the samples stored under MAP in laminated pouches, banana chips prepared by directly adding 0.02% of oven dried curry leaf powder into frying oil recorded lowest peroxide value of 7.87 meq. O_2/kg at 90 days of storage which was on par with banana chips prepared by direct addition of 0.02% fresh banana peel into frying oil (8.13 meq. O_2/kg). Control sample recorded a higher peroxide value (9.33 meq. O_2/kg).

Among the three packaging systems tried, banana chips prepared by directly adding 0.02% of oven dried curry leaf powder or fresh banana peel into the frying oil and packaged under MAP in laminated pouches recorded lowest peroxide values, 7.87 meq. O_2/kg and 8.13 meq. O_2/kg respectively at 90 days of storage. Highest peroxide value was recorded by untreated samples in LDPE pouches (12.80 meq. O_2/kg) (Table 11.).

4.2.2. c. *Iodine Value*

Among the samples packed in LDPE pouches, a higher iodine value 7.96 was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder at 90 days of storage. Control sample recorded the lowest iodine value of 6.51.

When chips were stored in laminated pouches, a higher iodine value (9.26) was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder at 90 days of storage. Control sample recorded a lower iodine value of 6.51.

Among the samples packaged under MAP in laminated pouches, the highest iodine value (10.27) was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder at 90 days of storage. Control sample recorded a lower iodine value (8.29).

Among the three packaging systems tried, banana chips prepared by directly adding 0.02% of oven dried curry leaf powder into the frying oil and packaged under MAP in laminated pouches recorded the highest iodine value (10.27) at 90 days of storage. The lowest iodine value (6.51) was recorded by untreated chips packaged in LDPE pouches and laminated pouches (Table 12.).

4.2.2. d. *Total Antioxidant Activity*

Curry leaf treated chips had maximum (9.89 ± 0.99 %) antioxidant activity when packaged in LDPE pouches at 90 days of storage. Untreated sample recorded the lowest antioxidant activity (3.89 ± 0.39 %) (Table 13.).

Among the samples stored in laminated pouches, a higher antioxidant activity, 12.52 ± 1.26 % was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder at 90 days of storage. Untreated sample recorded a lower antioxidant activity (4.36 ± 0.44 %).

Among the samples packaged under MAP in laminated pouches, the highest antioxidant activity (12.61 ± 1.23 %) was recorded by banana chips prepared by directly adding 0.02% oven dried curry leaf powder at 90 days of storage. Untreated sample recorded a lower antioxidant activity (4.80 ± 0.48 %) at 90 days of storage.

Among the three packaging systems tried, banana chips prepared by directly adding 0.02% of oven dried curry leaf powder into the frying oil and packaged under MAP in laminated pouches recorded the highest antioxidant

Table 12. Iodine value of chips during storage in different packaging materials

Treatments	IODINE VALUE						
	Days after storage						
	Initial	15	30	45	60	75	90
	LDPE						
Fresh banana peel	11.63	11.25	10.37	9.64	8.80	8.20	7.11
Curry leaf powder	12.56	11.63	11.15	10.06	9.35	8.63	7.96
Control	10.96	9.94	9.56	8.75	8.25	7.57	6.51
	Laminated pouch						
Fresh banana peel	11.72	11.31	10.91	10.41	9.81	9.31	8.84
Curry leaf powder	12.60	11.63	11.21	10.78	10.15	9.56	9.26
Control	10.70	10.06	9.68	9.17	8.25	7.27	6.51
	MAP						
Fresh banana peel	11.80	11.51	11.10	10.57	10.11	9.56	9.22
Curry leaf powder	12.94	12.65	12.30	11.63	11.18	10.74	10.27
Control	10.65	10.16	9.76	9.52	9.14	8.63	8.29
CD (P=0.05)	0.34	0.29	0.29	0.20	0.25	0.24	0.35

Table 13. Total antioxidant activity of chips during storage in different packaging materials.

TOTAL ANTIOXIDANT ACTIVITY (%)				
Treatments	Days after storage			
	Initial	30	60	90
	LDPE			
Fresh banana peel	12.21 ± 1.25	10.64 ± 1.03	9.00 ± 0.93	7.08 ± 0.72
Curry leaf powder	17.36 ± 1.77	15.26 ± 1.50	12.16 ± 1.25	9.89 ± 0.99
Control	6.89 ± 0.71	5.87 ± 0.57	4.92 ± 0.51	3.89 ± 0.39
	Laminated pouch			
Fresh banana peel	13.48 ± 1.37	12.52 ± 1.21	11.03 ± 1.14	10.25 ± 1.03
Curry leaf powder	15.16 ± 1.55	14.35 ± 1.40	13.62 ± 1.40	12.52 ± 1.26
Control	7.50 ± 0.76	6.66 ± 0.65	5.38 ± 0.55	4.36 ± 0.44
	MAP in laminated pouch			
Fresh banana peel	12.79 ± 1.31	12.32 ± 1.20	11.69 ± 1.20	10.90 ± 1.10
Curry leaf powder	14.71 ± 1.50	13.90 ± 1.35	13.23 ± 1.36	12.61 ± 1.23
Control	7.32 ± 0.75	6.02 ± 0.58	5.43 ± 0.56	4.80 ± 0.48
CD (P=0.05)	2.09	1.80	1.69	1.47

activity (12.61 ± 1.23 %) at 90 days of storage which was on par with the samples packaged in laminated pouches (12.52 ± 1.26%). The lowest antioxidant activity (3.89 ± 0.39 %) was recorded by untreated samples packed in LDPE pouches, laminated pouches (4.36 ± 0.44%) or MAP in laminated pouches (4.80 ± 0.48%) (Table 13.).

4.2.3. Changes in Sensory Quality

Appearance, colour, flavour, taste, texture and overall acceptability of antioxidant treated chips stored in different packaging materials for a period of three months were evaluated organoleptically and mean ranks for each attribute are presented in Table 14.

4.2.3. a. *Appearance*

Among the samples packed in LDPE pouches the highest mean rank value (18.20) was recorded for banana chips prepared by directly adding 0.02% fresh banana peel to frying oil at 90 days of storage. Untreated samples recorded the lowest mean rank value (15.75).

When the samples were stored in laminated pouches for 90 days of storage the highest mean rank value (65.40) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil which was on par with chips prepared by adding fresh banana peel (52.80). Control samples recorded a lower mean rank value (33.90).

Among the samples stored under MAP in laminated pouches for 90 days, the highest mean rank value (75.60) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil, which was on par with chips prepared after addition of fresh banana peel (71.00). The lower mean rank value (60.00) was recorded by untreated chips.

When the packaging systems were compared, the highest mean rank value for appearance (75.60) was recorded by banana chips prepared after addition of 0.02% curry leaf powder into frying oil and packaged under MAP in laminated

Table 14. Mean ranks of chips during storage in different packaging materials

Attributes	LDPE							Laminated pouch							MAP						
	Days after storage							Days after storage							Days after storage						
Appearance	Initial	15	30	45	60	75	90	Initial	15	30	45	60	75	90	Initial	15	30	45	60	75	90
Fresh banana peel	41.95	45.30	35.60	28.20	18.90	19.30	18.20	43.40	43.80	51.80	54.65	58.45	51.10	52.80	46.10	47.85	53.00	63.80	68.50	68.55	71.00
Curry leaf powder	48.80	47.85	32.75	19.60	18.90	19.80	16.90	46.10	47.90	49.10	60.75	58.45	65.40	65.40	54.40	43.80	54.65	63.35	74.15	76.95	75.60
Control	39.25	39.30	28.85	28.20	19.80	17.70	15.75	43.40	45.90	49.10	43.35	39.10	31.40	33.85	46.10	47.85	54.65	47.70	53.40	59.30	60.00
Colour																					
Fresh banana peel	46.80	44.90	45.60	28.10	31.70	39.50	34.40	43.50	48.30	52.40	44.20	59.20	56.90	61.55	46.70	45.30	58.10	60.55	64.30	67.20	66.35
Curry leaf powder	43.50	41.90	37.30	29.10	26.70	30.55	35.25	45.30	47.90	50.20	57.75	62.95	68.50	68.70	46.70	48.70	52.40	65.85	69.20	74.20	73.85
Control	49.90	41.90	32.90	24.70	12.90	10.25	11.45	40.40	45.30	41.00	48.30	28.45	16.30	13.95	46.70	45.30	39.60	51.05	54.15	46.10	44.00
Flavour																					
Fresh banana peel	39.75	33.70	18.75	25.60	24.10	21.90	20.30	31.85	30.20	29.10	42.95	45.15	48.40	57.20	35.80	28.85	37.50	49.15	67.95	74.60	73.85
Curry leaf powder	69.50	63.20	48.00	40.70	34.80	31.35	27.00	55.15	47.20	63.60	62.40	59.30	50.65	61.90	62.15	52.00	70.40	68.00	74.05	71.90	77.40
Control	35.80	27.30	30.90	17.70	13.40	19.60	10.25	39.75	62.00	46.60	44.05	36.30	27.85	33.35	39.75	65.15	64.70	59.00	54.55	63.25	48.25
Taste																					
Fresh banana peel	40.10	44.70	19.45	21.60	24.30	26.20	33.10	34.00	44.70	42.10	52.00	59.00	57.05	58.90	40.65	49.20	63.85	72.90	78.45	74.40	72.30
Curry leaf powder	61.15	38.40	50.70	31.30	29.30	24.10	20.40	53.95	41.10	62.60	52.00	56.50	55.00	62.55	61.15	58.20	68.65	73.20	71.90	76.45	81.95
Control	37.75	41.10	21.60	20.60	13.20	12.85	13.20	37.05	44.70	40.90	40.00	30.00	28.70	20.60	43.70	47.40	39.80	46.00	46.90	54.75	46.50
Texture																					
Fresh banana peel	54.10	47.65	33.30	30.40	25.70	26.00	16.65	44.70	38.10	47.10	55.15	51.20	44.10	53.10	44.70	48.45	62.70	63.95	60.10	74.60	72.55
Curry leaf powder	47.60	42.35	32.70	32.00	35.60	28.80	20.05	41.80	35.50	57.60	53.35	58.40	70.15	66.15	51.20	47.65	60.80	69.25	69.90	68.35	72.55
Control	44.70	51.10	17.60	7.60	8.90	11.50	13.65	41.80	48.50	42.00	41.70	36.90	28.80	37.80	38.90	50.30	55.70	56.20	62.80	57.20	57.00
Overall acceptability																					
Fresh banana peel	41.50	40.50	30.50	20.70	20.90	21.65	23.90	28.00	36.00	41.00	56.70	53.40	51.75	58.75	41.50	45.00	56.80	63.15	68.15	71.30	73.80
Curry leaf powder	64.00	49.50	37.50	24.50	28.20	25.65	20.10	46.00	45.00	56.80	63.15	62.85	65.25	64.90	64.00	54.00	72.60	73.75	76.75	78.90	79.50
Control	41.50	31.50	16.50	13.30	9.30	10.55	10.30	41.50	49.50	45.00	33.90	30.30	25.95	27.70	41.50	58.50	52.85	60.50	59.70	58.50	50.55
CV value	22.89																				

pouches as well as samples packed in laminated pouches (65.4). The lowest mean rank value (15.75) recorded by the untreated chips packed in LDPE pouches was on par with the sample packed in laminated pouches (33.90).

4.2.3. b. ***Colour***

When the samples were stored in LDPE pouches for 90 days, the highest mean rank value (35.25) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil which was on par with chips prepared after adding fresh banana peel (34.40). Untreated chips recorded the lowest mean rank value (11.45).

Among the samples packed in laminated pouches, the highest mean rank value (68.70) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil at 90 days of storage, which was on par with chips prepared after addition of fresh banana peel (61.55). Untreated chips recorded the lowest mean rank value (13.95).

When the samples were packaged under MAP in laminated pouches for 90 days, the highest mean rank value (73.85) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder to frying oil which was on par with chips prepared after adding fresh banana peel (66.35). The lowest mean value (44.00) was recorded by untreated chips.

4.2.3. c. ***Flavour***

Among the samples packed in LDPE pouches the highest mean rank value (27.00) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil which was on par with chips prepared after adding fresh banana peel (20.30) and untreated samples (10.25).

When the samples are stored in laminated pouches for 90 days, the highest mean rank value (61.90) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil which was on par with chips prepared after addition of fresh banana peel (57.20). Untreated chips recorded a lower mean rank value (33.35).

Among the samples packaged under MAP in laminated pouches, the highest mean rank value (77.40) was recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder to frying oil at 90 days of storage which was on par with chips prepared after addition of fresh banana peel (73.85) and a lower value (48.25) was recorded by untreated chips.

4.2.3. d. *Taste*

When the samples are packed in LDPE pouches, the highest mean rank value (33.10) was recorded by banana chips prepared after adding 0.02% fresh banana peel to frying oil at 90 days of storage which was on par with chips prepared using dried curry leaf powder (20.40) as well as untreated chips (13.20).

Among the samples packed in laminated pouches, the highest mean rank value (62.60) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder to frying oil at 90 days of storage which was on par with chips prepared after addition of banana peel (58.90). Untreated chips recorded a lower mean rank value (20.60).

When the samples were stored under MAP in laminated pouches for 90 days, the highest mean rank value (81.95) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder to frying oil, which was on par with chips prepared after addition of banana peel (72.30). Lower mean rank value (46.50) was recorded by untreated chips.

4.2.3. e. *Texture*

All the chips samples stored in LDPE pouches recorded similar mean rank value for texture at 90 days of storage.

Among the samples packed in laminated pouches the highest mean rank value (66.15) was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder to frying oil at 90 days of storage which was on par with chips prepared by direct addition of fresh banana peel (53.10). Control samples recorded a lower mean rank value (37.80).

Among the samples packaged under MAP in laminated pouches, the highest mean rank value (72.55) on 90 days of storage was recorded by banana chips prepared by adding 0.02% oven dried curry leaf powder and fresh banana peel to frying oil and the lowest value (57.00) was recorded by control samples.

4.2.4. f. *Overall Acceptability*

All the samples stored in LDPE pouches had similar mean rank value for overall acceptability at 90 days of storage. However, banana chips prepared after addition of 0.02% fresh banana peel to frying oil recorded highest mean rank value (23.90).

Among the samples packed in laminated pouches, the highest mean rank value (64.90) was recorded by banana chips prepared by directly adding 0.02% dried curry leaf powder to frying oil at 90 days of storage, which was on par with chips prepared after adding fresh banana peel (58.75). Untreated chips recorded a lower mean rank value (27.70).

When the samples were stored under MAP in laminated pouches, the highest mean rank value (79.50) was recorded by banana chips prepared by direct addition of 0.02% dried curry leaf powder to frying oil at 90 days of storage which was on par with chips prepared after adding fresh banana peel (73.80). The lowest mean rank value (50.55) was recorded by untreated chips.

4.3. DEVELOPMENT OF FLAVOURED BANANA CHIPS

4.3.1. Organoleptic Evaluation of Flavoured Chips

Flavoured banana chips were developed by adding different types of flavour imparting substances like garlic, black pepper, curry leaves and coriander leaves in two different forms at two different concentrations. The developed flavoured chips were subjected to preliminary evaluation by conducting organoleptic studies and mean rank values for each attribute are presented in Table 15.

Table 15. Mean sensory rank values of flavoured banana chips

MEAN SENSORY RANK VALUES					
	GARLIC				
Treatments	Appearance	Colour	Flavour	Taste	Texture
FC1	9.90	20.20	9.75	12.90	16.50
FC2	11.90	17.40	11.65	12.90	15.80
PC1	29.15	21.55	26.20	21.25	24.00
PC2	31.05	22.85	34.40	34.95	25.70
	BLACK PEPPER				
FC1	19.35	20.50	12.10	16.00	22.10
FC2	21.35	22.50	12.10	14.50	20.50
PC1	20.80	20.50	22.30	16.00	20.50
PC2	20.50	18.50	35.50	35.50	18.90
	CURRY LEAF				
FC1	12.00	12.00	16.65	18.55	15.80
FC2	9.90	14.95	19.55	15.45	17.50
PC1	29.30	29.85	17.10	18.55	15.80
PC2	30.80	25.20	28.70	29.45	17.50
	CORIANDER LEAVES				
FC1	15.25	20.55	17.20	14.50	19.20
FC2	15.80	19.00	14.40	16.00	17.50
PC1	20.35	19.00	14.90	16.00	22.70
PC2	30.60	23.45	35.50	35.50	22.60
CV	**10.25**				

Table 16. Mean scores of flavoured banana chips prepared from selected superior treatments

Attributes	Garlic	Black Pepper	Curry leaf	Coriander leaves
Appearance	8.10	6.40	7.10	6.10
Colour	7.90	7.20	7.20	6.20
Flavour	9.10	6.00	7.40	4.10
Taste	9.00	5.40	7.20	4.50
Crispness	8.30	7.30	8.00	6.60

4.3.1.a. *Sensory Quality of Garlic Flavoured Chips*

Highest mean rank value for appearance (31.05) was recorded by banana chips prepared by adding 2% oven dried garlic powder which was on par with chips prepared by 1% garlic powder addition (29.15). Lowest mean rank value was recorded by 1% fresh garlic (9.90) which was on par with 2% fresh garlic added chips (11.90).

Two percentage oven dried garlic powder added to banana chips recorded highest mean rank value for flavor (34.40) which was on par with chips prepared by addition of 1% oven dried garlic powder (26.20). Chips with 1% and 2% fresh garlic recorded low mean rank values of 9.75 and 11.65 respectively.

A significantly higher mean rank value for taste (34.95) was recorded by addition of 2% oven dried garlic powder. Fresh garlic applied at 1% and 2% concentrations recorded the least value (12.90) which was on par with the addition of 1% oven dried garlic powder (21.25).

No significant difference existed between the banana chips regarding colour and textural attributes.

4.3.1.b. *Sensory Quality of Black Pepper Flavoured Chips*

Highest mean rank value for flavour (35.50) was recorded by banana chips prepared by adding 2% oven dried black pepper powder. Lowest mean rank value (12.10) was recorded by banana chips prepared by the addition of 1% and 2% fresh black pepper which was on par with 1% oven dried black pepper powder addition (22.30).

Two percentage oven dried black pepper powder added chips recorded highest mean rank value for taste (35.50) whereas fresh black pepper applied at the same concentration recorded lowest mean rank value for taste (14.50). The treatments showed no significant difference for appearance, colour and texture.

4.3.1.c. *Sensory Quality of Curry Leaf Flavoured Chips*

Highest mean rank value for appearance (30.80) was recorded by banana chips prepared by adding 2% oven dried curry leaf powder which was on par with the addition of same at 1% (29.30). Lowest mean rank value was recorded by banana chips added with 2% fresh curry leaves (9.90) which was on par with the same added at 1% (12.00).

Highest mean rank value for colour (29.85) was recorded by banana chips prepared by adding 2% oven dried curry leaf powder which was on par with the addition of same at 1% (25.20). Lowest mean rank value was recorded by banana chips added with 1% fresh curry leaves (12.00) which was on par with the same added at 2% (14.95).

Chips prepared with oven dried curry leaf powder (28.70) or fresh curry leaves (19.55) at 2% recorded higher mean rank values for flavour. Application of 2% fresh curry leaves (19.55) was on par with addition of 1% of fresh curry leaves (16.65) or 1% oven dried curry leaf powder (17.10) which had lower mean rank values for flavour.

A significantly higher mean rank value for taste (29.45) was recorded by banana chips added with 2% oven dried curry leaf powder. Lowest mean rank value was recorded by 2% fresh curry leaf addition which was on par with the addition of 1% fresh leaves or oven dried powder (18.55).

There was no significant difference between treatments with respect to its texture.

4.3.1.d. *Sensory Quality of Coriander Leaf Flavoured Chips*

Highest mean rank value for appearance (30.60) was recorded by banana chips prepared by adding 2% oven dried coriander leaf powder which was on par with the addition of same at 1% (20.35). Lowest mean rank value was recorded by banana chips flavoured with 1% fresh coriander leaves (15.25) which was on par with the same added at 2% (15.80) and also chips added with 1% oven dried coriander leaf powder (20.35).

Highest mean rank value for flavour (35.50) was recorded by banana chips prepared by adding 2% oven dried coriander leaf powder. Lowest mean rank value was recorded by banana chips added with 2% fresh coriander leaves

(14.40) which was on par with the same added at 1% (17.20) and also 1% oven dried coriander leaf powder (14.90).

Oven dried coriander leaf powder applied to frying oil at 2% concentration recorded the highest mean rank value for taste (35.50). Application of 1% fresh coriander leaves (14.50) recorded the lowest mean rank value which is on par with the same applied at 2% concentration (16.00) and application of 1% oven dried coriander leaf powder (16.00).

No significant difference existed between treatments with respect to its colour and texture.

Considering the overall performance of the samples, the application of 2% concentration of flavor imparting substances in powder form was selected for further study.

4.3.2. Consumer Acceptability Study of Selected Flavoured chips

Flavoured banana chips were prepared using the above four flavour imparting substances by adding its oven dried powdered form at 2% concentration directly into frying oil. Appearance, colour, flavour, taste and crispness of the flavoured chips were evaluated by sensory panel and the mean rank value recorded (Table 16.).

Highest scores for appearance (8.10), colour (7.90), flavour (9.10), taste (9.00) and crispness (8.30) were recorded by garlic flavoured chips which was closely followed by curry leaf flavoured chips with a score of 7.10 for appearance, 7.20 for colour, 7.40 for flavour, 7.20 for taste and 8.00 for crispness. Black pepper and coriander leaf flavoured chips recorded comparatively lower scores for all the attributes.

4.4. COST OF PRODUCTION

Cost of production. of 1kg chips prepared using 0.02% dried curry leaf powder was calculated as Rs. 455.25/- whereas flavoured chips produced using 2% garlic powder was calculated as Rs. 470.25/-.

Discussion

5. DISCUSSION

The results obtained from the investigation on "Development of Nendran banana chips with enhanced shelf life and quality" are discussed in this chapter under three headings.

5.1. Effect of antioxidants on quality of banana chips

5.2. Storage potential of treated banana chips

5.3. Development of flavoured banana chips

5.1. EFFECT OF ANTIOXIDANTS ON QUALITY OF BANANA CHIPS

5.1.1. Effect of Processing Waste in Controlling Rancidity of Banana Chips

Four different processing wastes, rich in antioxidants viz., banana peel, potato peel, watermelon peel and cucumber peel, were incorporated in its fresh and oven dried powdered forms by two methods in Nendran banana chips prepared in unrefined coconut oil.

Quality is an attribute or a property which is a measure of excellence (Houhoula, 2004). Consumer acceptability tests in the form of appropriate sensory analysis and other physical and chemical analysis are important part of quality and shelf life evaluation of any snack products (Lawless, 1995). So, antioxidants incorporated chips were evaluated for physical, chemical and sensory quality parameters and the best antioxidant was selected from each set of antioxidants for further storage study.

5.1.1.a. *Effect of Processing Waste on Physical Quality of Banana Chips*

Banana chips should have low moisture content and oil uptake for good shelf life (Dominic, 2002). At the same time it should have high integrity and low shrinkage for good physical appearance. Yield is an essential factor to be considered along with these quality parameters.

Banana chips prepared by direct addition of 0.02% fresh banana peel into frying oil (A1F1C2M2) recorded low moisture content (6.45%) and oil uptake (30.65%) with a low yield (65.6%). At the same time, banana chips prepared from slices presoaked in 0.02% oven dried banana peel powder (A1F2C2M1) with the highest yield (77.10%) had a higher oil uptake (38.05%) and maximum moisture content (9.00%). It could be noted that there is a negative correlation between yield and quality parameters like moisture content and oil uptake. Presoaking banana slices results in an increased moisture content which increases the chance for more oil absorption and hence higher yield. In the present study treatments which had resulted in low yield was having good quality parameters.

When the influence of method of antioxidant application on moisture content of banana chips was examined, it could be seen that applying antioxidants directly to frying oil had less moisture content and hence better than presoaking slices with antioxidants. A higher moisture content of 9.0% was also observed by chips prepared from slices presoaked in oven dried cucumber peel powder (A4F2C1M1), whereas chips prepared by addition of 0.02% fresh watermelon peel (A3F1C2M2) recorded the lowest moisture content of 6.3%. This agrees with the findings of Adrika (2011) who had reported that presoaked slices with antioxidants recorded higher moisture content compared to direct antioxidant addition to frying oil. The result was found to be same in all the antioxidants tried. (Fig 2a – 2d.).

For a good quality banana chips, the other two physical quality parameters to be considered are high integrity and low shrinkage. Banana chips prepared by direct addition of 0.02% fresh banana peel into frying oil (A1F1C2M2) recorded high integrity (84.45%) and low shrinkage (21.00%) too.

When the influence of antioxidant application method on these parameters was examined, it could be seen that applying antioxidants directly to frying oil had resulted in high integrity (Plate 12.) and less shrinkage compared to presoaking slices with antioxidants. Highest integrity was recorded by chips prepared with direct addition of 0.01% oven dried banana peel powder (84.60%) whereas chips prepared by direct addition of 0.02% fresh potato peel recorded lowest shrinkage (20.90%).

Fried foods shrink when the moisture is lost and the food cells collapse as a consequence of heating and evaporation during frying. A decrease in the product

Plate 11. Banana chips with higher oil uptake

Plate 12. Banana chips with poor integrity

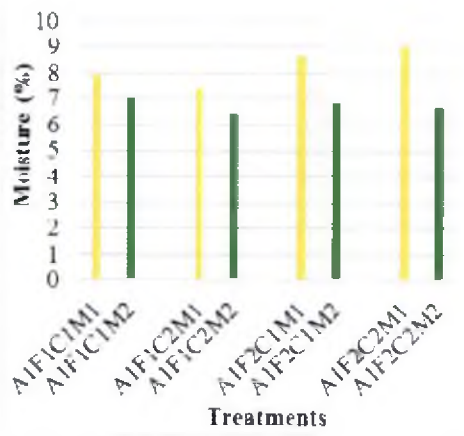


Fig 2. a. Banana peel

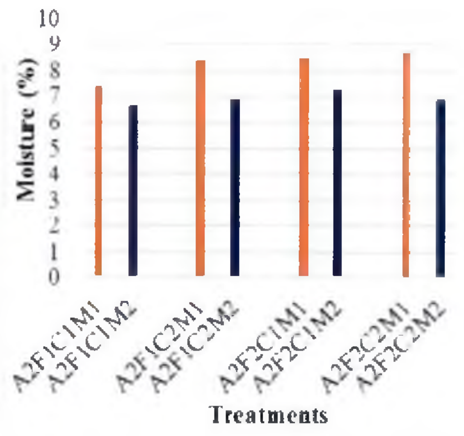


Fig 2. b. Potato peel

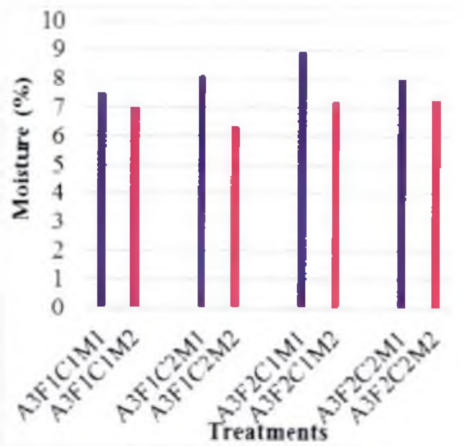


Fig 2. c. Watermelon peel

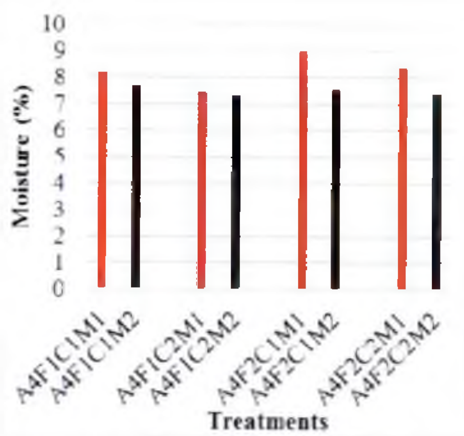


Fig 2. d. Cucumber peel

Fig 2. Effect of processing waste and method of application on moisture content dimension occurs when heat – induced evaporation / drying is done (Krokida *et al.*, 2000). Shrinkage starts as a surface occurance, since drying during frying initiates at the surface and then progresses into the sample with the frying time. When the drying rate is high, the crust forms quickly, hence reducing the rate of moisture, which causes the shape of the product to form faster with minimal shrinkage.

Considering all the above physical quality parameters together, 0.02% fresh banana peel was found to be the best processing waste and direct addition in oil during smoke point was found to be the best method of application for producing chips with good physical attributes. Banana chips prepared by direct addition of 0.02% fresh banana peel to frying oil recorded lowest moisture content (6.45%) (Fig. 3.a.), oil uptake (30.65%) (Fig. 3.b.), shrinkage (21.00) (Fig 3.d.) and a higher integrity (84.45%) (Fig.3.c.).

5.1.1.b. *Effect of Processing Waste on Chemical Quality of Banana Chips*

Banana chips prepared by the incorporation of antioxidant rich processing waste showed significant difference in chemical quality parameters like free fatty acid value (mg KOH/g), peroxide value (meq. O_2 / kg) and iodine value at three months of storage. Good quality banana chips should have low free fatty acid value, peroxide value and a high iodine value for enhanced shelf life.

When the effect of antioxidant rich processing waste on free fatty acid value of banana chips was studied, the lowest FFA value (3.08 mg KOH/g) (Fig 4.a.) was recorded by banana chips prepared by direct addition of 0.02% fresh banana peel into frying oil. Chips prepared by the same method recorded lowest peroxide value (4.70 meq. O_2 / kg) (Fig 4.b.) and highest iodine value (8.76) (Fig 4.c.) indicating its superiority. Banana chips prepared by direct addition of 0.01% fresh banana peel to frying oil also recorded lowest peroxide value (4.70 meq. O_2 / kg). When the efficiency of form of antioxidant was compared fresh banana peel was better compared to oven dried powdered form.

A large range of low and high molecular weight plant polyphenols with antioxidant properties has been studied and proposed for protection against lipid

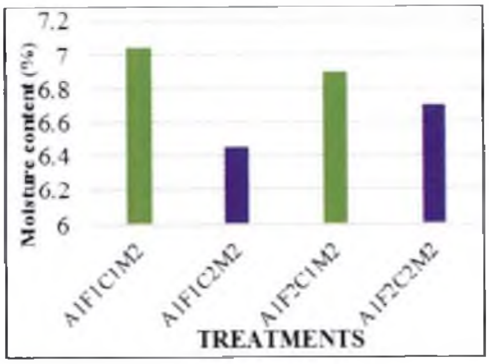


Fig 3. a. Moisture content

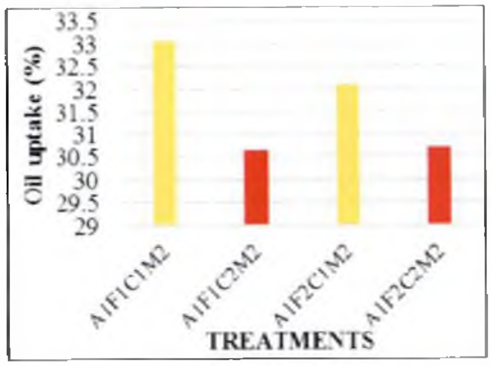


Fig 3. b. Oil uptake

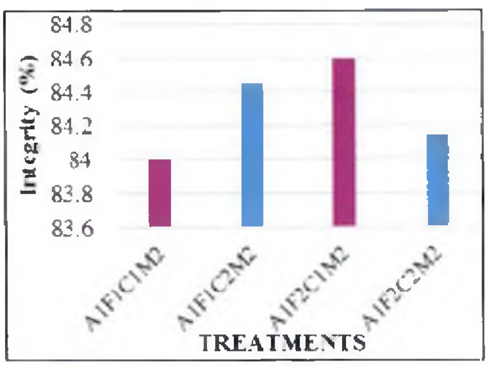


Fig 3. c. Integrity

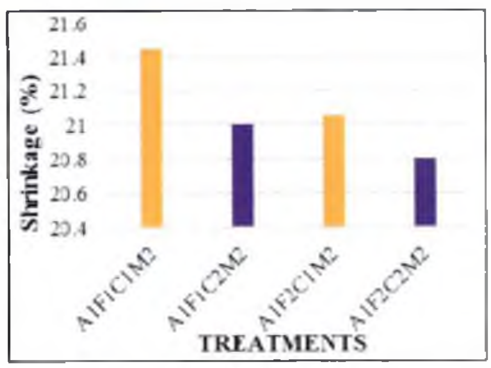


Fig 3. d. Shrinkage

Fig 3. Efficiency of banana peel in improving physical quality parameters of chips

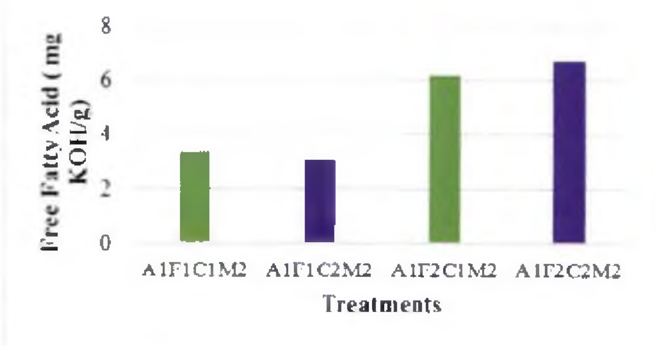


Fig 4. a. Free fatty acid value

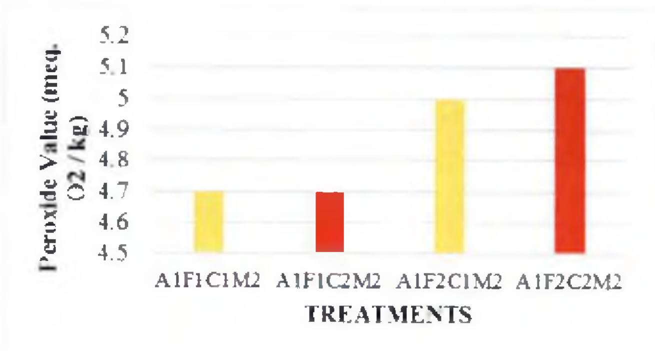


Fig 4. b. Peroxide value

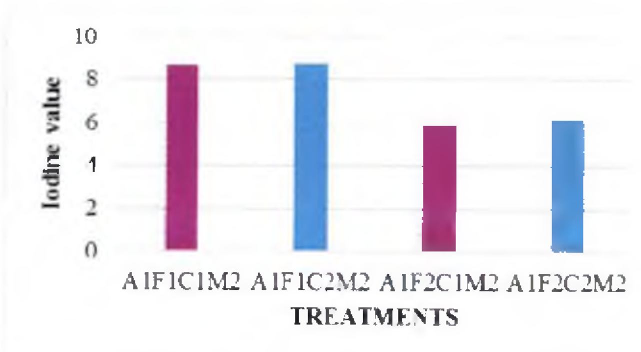


Fig 4. c. Iodine value

Fig 4. Effect of banana peel on chemical quality parameters oxidation (Par and Bolwell, 2000). Total phenolic content of Nendran is 0.49 +/- 0.06mg catechol equivalents/g fresh tissue (Baskar *et al.*, 2011). Phenolics are stored in pectin or cellulose networks of plants which can be released during thermal processing. Heat during deep frying of chips will break the supramolecular structure which might make the phenolic compounds react better with the reagents (Bunea *et al.*, 2008).

Higher iodine value are recorded by banana chips prepared from banana peel as antioxidants compared to other peels. This is in accordance with findings of Nagarajaiah and Prakash (2011), who had reported that banana peel has good antioxidant potential which may be attributed to compounds like gallocatechin (Kanazawa and Sakakibara, 2000) and dopamine (Someya *et al.*, 2002).

The highest FFA value was recorded by banana chips prepared from slices presoaked in 0.01% oven dried cucumber peel powder (12.30 mg KOH/g) and those soaked in 0.02% oven dried water melon peel powder recorded the highest peroxide value (9.40 meq. O_2 / kg). Chitturi *et al.* (2013) reported that antioxidant concentration was lower in water melon (0.08%). Chips prepared by presoaking slices in 0.01% of fresh potato peel recorded lowest iodine value (5.78). All these suggest that other fruit peels are inferior to banana peel.

5.1.1.c. *Effect of Processing Waste on Sensory Quality of Banana Chips*

Quality of a food involves maintenance or improvement of its key attributes such as colour, flavour, texture etc. (Houhoula, 2004). Hence, banana chips prepared by adding antioxidant rich processing waste were subjected to a sensory analysis and the chips showed significant difference in sensory quality parameters like appearance, colour, flavour, taste, texture and overall acceptability.

The chips prepared by adding 0.02% fresh banana peel to frying oil recorded highest mean rank value for colour (223.50), taste (266.90), texture (248.80) and overall acceptability (268.10). The chips with highest physical and chemical quality attributes were supported with high sensory scores too.

The lowest mean rank value for appearance (77.2) was recorded by banana chips prepared after presoaking slices in 0.02% fresh water melon peel. The lowest mean rank value for colour (75.8) was recorded by banana chips prepared from slices presoaked in 0.01% oven dried watermelon peel powder. The lowest mean rank value for texture (102.80) was recorded by banana chips prepared from slices presoaked in 0.01% oven dried banana peel powder. The lowest mean rank value for flavour (83.40), taste (82.80) and overall acceptability (86.90) were recorded by banana chips prepared from slices presoaked in 0.02% oven dried cucumber peel powder. Slices presoaked in 0.01% oven dried cucumber peel powder also recorded lowest mean rank value for taste (82.8) and overall acceptability (86.90). It was seen that least sensory quality attributes were recorded by banana chips prepared after presoaking slices in antioxidants. Presoaking for 30 minutes resulted in loss of integrity, high moisture absorption and oil uptake which might have affected all the sensory scores negatively.

Based on superior physical, chemical and sensory quality parameters addition of 0.02% fresh banana peel to frying oil at smoke point was selected as the best treatment for further storage study.

5.1.2. Effect of Flavour Imparting Substances in Controlling Rancidity of Banana Chips

Nendran banana chips were prepared in unrefined coconut oil by addition of two forms of antioxidant rich flavour imparting substances viz., garlic, black pepper, curry leaf and coriander leaves in two different methods. The treated chips were evaluated for their physical, chemical and sensory quality parameters.

5.1.2.a. *Effect of Flavour Imparting Substances on Physical Quality of Banana Chips*

Low moisture content and oil uptake are the essential parameters for a product with good shelf life (Dominic, 2002). At the same time it should have high integrity and low shrinkage for better physical appearance. Yield is an essential factor which should be considered along with these quality parameters.

Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder to frying oil recorded the least moisture content (5.30%) and oil uptake (31.40%), hence with the lowest yield (64.15%). Reduced yield in treated chips is due to reduced oil uptake and moisture content (Morias, 2006).

Banana chips prepared from slices presoaked in 0.01% fresh garlic recorded the highest moisture content (8.20%), yield (75.40%) and higher oil uptake (40.20%). Maximum oil uptake (42.05%) was recorded by banana chips prepared from slices presoaked with 0.01% oven dried coriander leaf powder. As in processing waste incorporated chips, negative correlation existed between yield and quality parameters like moisture content and oil uptake of chips prepared with flavor imparting substances.

The type and quality of frying oil and pretreatment prior to frying determine to a great extent the amount of oil that is absorbed and subsequently quality of the product (Adeniji, 2005). Presoaking banana slices in any solution results in an increased moisture absorption which increases the chance for more oil absorption and hence higher yield. During frying, the vapour escape paths eventually become an access for fat intrusion into a frying product resulting in more oil uptake.

Applying antioxidants directly to frying oil had less moisture content and hence better in quality than presoaking slices with antioxidants. This is in accordance with the findings of Adrika (2011) who had stated that 0.02% curry leaf powder when applied directly to frying oil resulted in lowest yield recovery , moisture content and oil uptake. The superiority of direct application of antioxidants in oil was observed in all flavor imparting substances tried. (Fig 5.).

For a good quality banana chips, the other two physical quality parameters to be considered are high integrity and low shrinkage. Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder to frying oil recorded high integrity (85.90%) and least shrinkage (20.90%), which are the other two essential physical quality parameters. This is in conformity with the findings of Adrika (2011) where, banana chips prepared by directly adding 0.02% curry leaf powder to frying oil recorded the highest (94.50%) integrity.

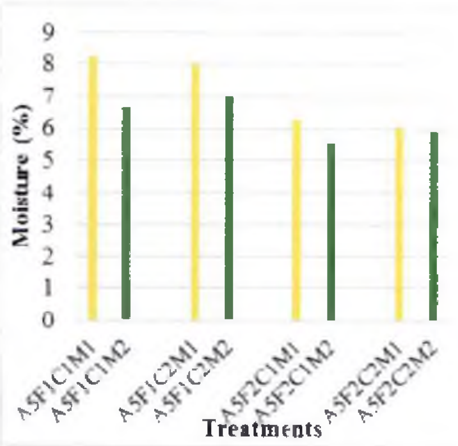


Fig 5. a. Garlic

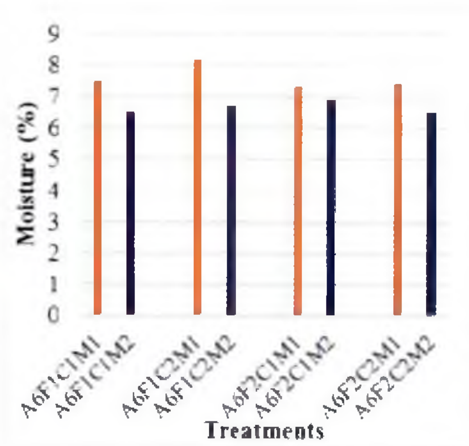


Fig 5. b. Black Pepper

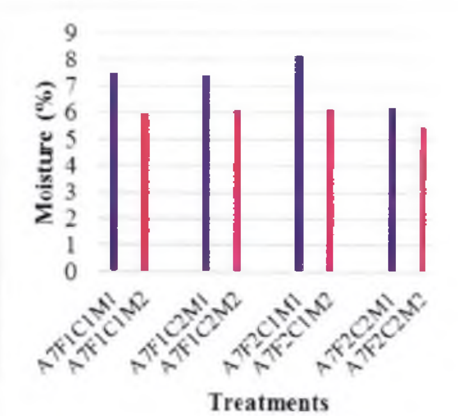


Fig 5. c. Curry leaf

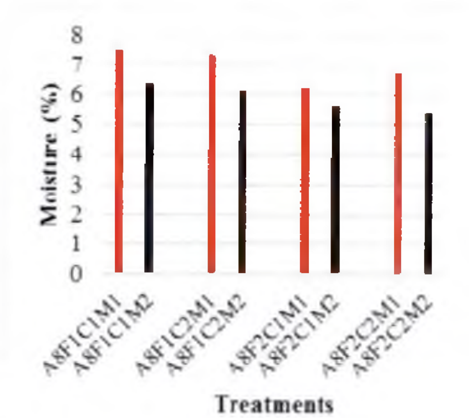


Fig 5. d. Coriander leaves

Fig 5. Effect of method of application on moisture content of chips

Highest integrity (86.10%) was also recorded by banana chips prepared by direct addition of 0.02% oven dried coriander leaf powder to frying oil. When the effect of method of antioxidant application on these parameters was compared, it could be seen that applying antioxidants directly to frying oil had resulted in high integrity and less shrinkage compared to presoaking slices with antioxidants.

When antioxidants are added to oil, chips had good integrity. During frying, moisture migrates from the interior of the food to its surface as a combination of vapour and water due to pressure and concentration gradients generated by heating, creating a porous system within the food (Sachin and Sumnu, 2009). Fried foods shrink when the moisture is lost and the food cells collapse as a consequence of heating and evaporation during frying. Product dimension decreases when heat induced evaporation/drying occurs (Krokida *et al.*, 2000).

Considering all the physical quality parameters together, 0.02% oven dried curry leaf powder was selected as the best flavour imparting substance and direct addition in oil during smoke point was found to be the best method for producing chips with good physical attributes. Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder to frying oil recorded lowest moisture content (5.30%) (Fig 6.a.), oil uptake (31.40%) (Fig 6.b.), shrinkage (20.90%) (Fig. 6.d.) and high integrity (85.90%) (Fig 6.c.).

5.1.2.b. ***Effect of Flavour Imparting Substances on Chemical Quality of Banana Chips***

Banana chips prepared by the incorporation of antioxidant rich flavour imparting substances showed significant difference in chemical quality parameters like free fatty acid value (mg KOH/g), peroxide value (meq. O_2 / kg) and iodine value at three months of storage. Good quality banana chips should have low free fatty acid value, peroxide value and a high iodine value for enhanced shelf life.

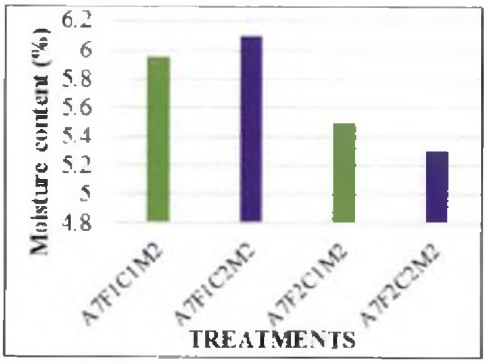


Fig 6. a. Moisture content

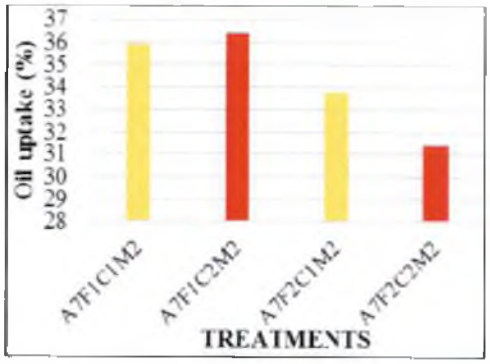


Fig 6. b. Oil uptake

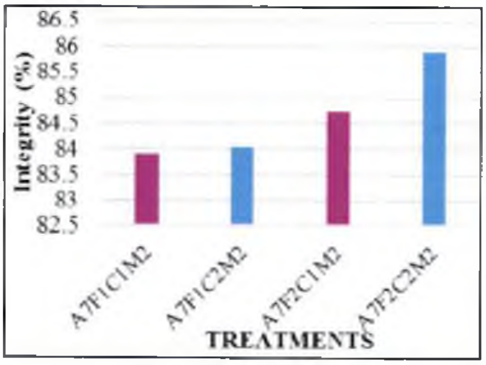


Fig 6. c. Integrity

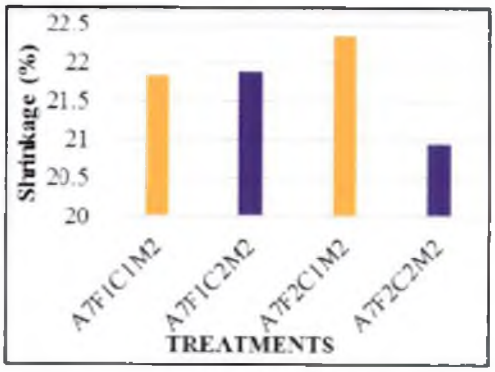


Fig 6. d. Shrinkage

Fig 6. Efficiency of curry leaf in improving physical quality parameters of chips

Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder into frying oil had low FFA value (3.02 mg KOH/g) (Fig 7.a.), peroxide value (6.50 meq. O_2 / kg) (Fig 7.b.) and highest iodine value (6.73) (Fig 7.c). indicating its superiority over other flavor imparting substances and method of application tried. This is in accordance with the findings of Adrika (2011) who had reported a low peroxide value when 0.02% of curry leaf powder is applied directly to frying oil. Banana chips prepared by direct addition of 0.02% oven dried coriander leaf powder also recorded the lowest FFA value (2.52 mg KOH/g) and peroxide value (6.20 meq. O_2 / kg).

Slices presoaked in 0.01% oven dried coriander leaf powder recorded the highest peroxide value (9.30 meq. O_2 / kg) and slices presoaked in 0.01% fresh garlic recorded the lowest iodine value (3.32).

5.1.2.c. *Effect of Flavour Imparting Substances on Sensory Quality of Banana Chips*

Banana chips produced by the incorporation of antioxidant rich flavour imparting substances showed significant difference in sensory quality parameters like appearance, colour, flavour, taste, texture and overall acceptability.

Appearance is the first factor that determine the acceptance or rejection of any food product (Almeida and Nogueira, 1995). Chips prepared by adding 0.02% oven dried curry leaf powder to frying oil scored highest mean rank value for appearance (281.20), which may be due to less oil uptake. Flavour also plays an important role in food acceptability. The highest mean rank values for flavour (284.10), colour (278.25), taste (282.80), texture (269.00) and over all acceptability (291.60) were also scored by the same treatment.

Banana chips prepared by slices presoaked in 0.01% fresh and oven dried curry leaf powder as well as slices presoaked in 0.02% fresh coriander leaves recorded the lowest mean rank value for appearance (122.40). The result agrees with the findings of Adrika (2011), who had reported that the banana chips prepared from slices presoaked in 0.02% curry leaf powder recorded the lowest value for appearance. The lowest mean rank value for colour (122.80) was

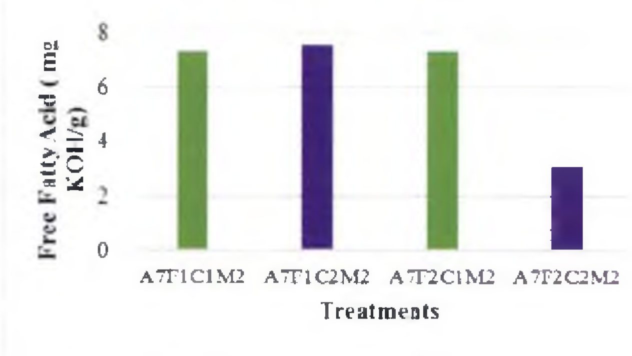


Fig 7. a. Free fatty acid value

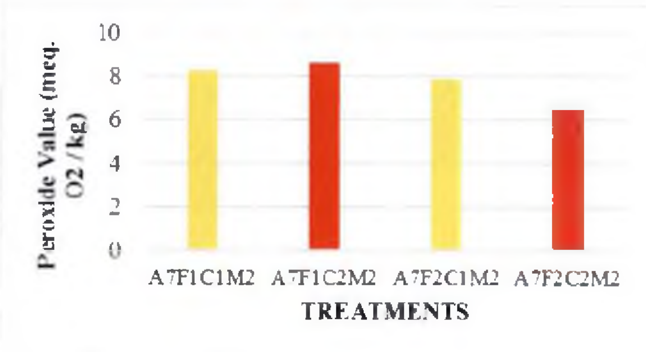


Fig 7. b. Peroxide value

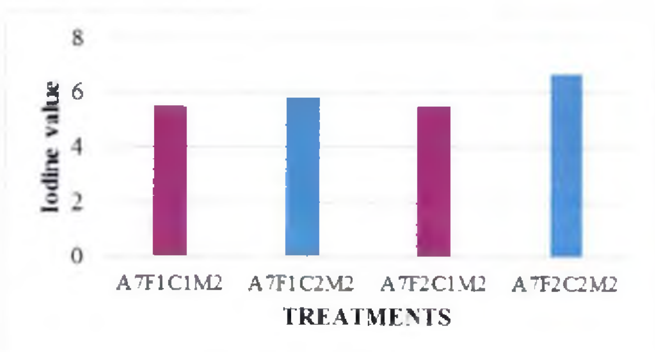


Fig 7. c. Iodine value

Fig 7. Effect of curry leaf powder on chemical quality parameters recorded by banana chips prepared from slices presoaked in 0.01% fresh curry leaves and 0.02% oven dried black pepper powder. Presoaking for 30 minutes results in adherence of antioxidant powders over the surface of chips decreasing the consumer acceptability. Also, a high oil content in fried banana chips shortens the shelf life of product and causes a decrease in product acceptability to consumers (Sothornvit, 2011).

The lowest mean rank value for flavour (112.90) was recorded by banana chips prepared from slices presoaked in 0.02% fresh garlic. By higher oil absorption during presoaking, the natural flavor of the antioxidants will be inhibited by the oil, thereby lowering the consumer acceptance resulting in low mean score for flavor and taste. In addition, the volatile compounds that comprise flavor may easily be lost, degraded or oxidized during processing steps (Winnie *et al.*, 2002) too. The lowest mean rank value for taste (114.50) was recorded by banana chips prepared from slices presoaked in 0.01% fresh curry leaves.

Textural attributes are also critical for a snack like banana chips (Winnie *et al.*, 2002). The lowest mean rank value for texture (123.95) was recorded by banana chips prepared from slices presoaked in 0.02% oven dried black pepper powder.

Direct addition of antioxidants in oil avoids all these negative factors, hence scoring higher mean rank for sensory parameters.

Based on superior physical, chemical and sensory quality parameters addition of 0.02% oven dried curry leaf powder to frying oil at smoke point was selected as the best treatment from flavor imparting substances for further storage study.

5.2. STORAGE POTENTIAL OF TREATED BANANA CHIPS

Packaging and storage are the two most important quality control factors of any processed food products, hence influencing its storage stability and shelf life. Good packaging and storage condition extend the storage duration of chips

(Anand *et al.,* 1982). The extent of food protection by packaging depends upon the type of materials used (Abong *et al.*, 2010). Chips quality attributes that require attention during storage include fat oxidation, flavoir alteration, peroxides, free fatty acids and moisture build up (Ogunsola and Omojola, 2008).

5.2.1. Changes in Physical Quality

Physical parameters of treated chips viz., moisture, colour and texture were measured and compared with untreated chips at regular intervals for a period of three months, after storing in three different packaging systems viz., LDPE pouch, laminated pouch and MAP in laminated pouch.

5.2.1. a. *Moisture Content*

Moisture content is an important shelf life determinant, the higher the level of moisture the faster the breakdown of oils in stored products. The effectiveness of storage conditions has been assessed in some instances by measuring the moisture content (Alam *et al.*, 2011). Snack foods may uptake water vapour from the surrounding environment since water vapour concentration gradient act as a driving force for the water vapour transport phenomenon through the packaging material (Howarth, 1994).

Banana chips stored in each type of packaging material had similar moisture content during initial storage period. As storage progressed the moisture content decreased in all treatments irrespective of treatments and packaging materials. Moisture content of chips is dependent on relative humidity of the storage structure. Molla *et al.* (2009) reported that chips stored in different packaging materials absorb moisture thereby gaining more weight. But the rate of increase was lower for chips stored under MAP in laminated pouches compared to those stored in laminated and LDPE pouches (Fig 8.a,b,c).

When the moisture content of treated and untreated chips were compared, it could be seen that the treated chips had a lower moisture content compared to untreated chips in all packaging materials throughout the storage period. The result agrees with the findings of Adrika (2011).

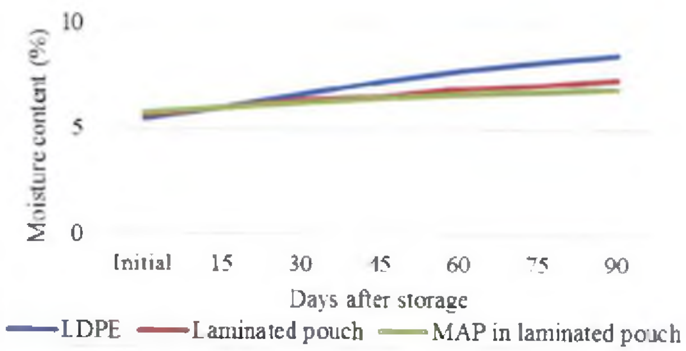


Fig 8. a. Curry leaf powder treated chips

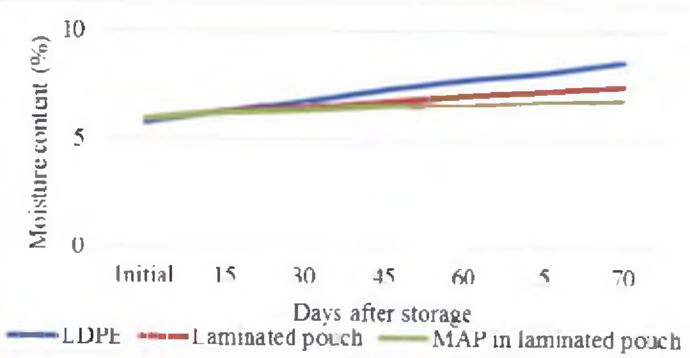


Fig 8. b. Fresh banana peel treated chips

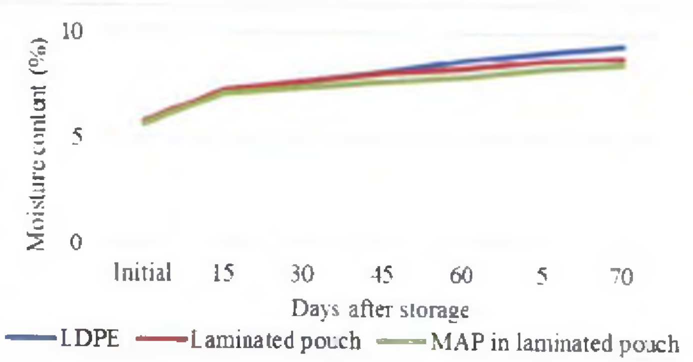


Fig 8. c. Untreated chips

Fig 8. Moisture content of chips stored under different packaging systems

Fresh banana peel and dried curry leaf powder were equally effective in maintaining low moisture content of treated chips.

When the combined effect of packaging material and antioxidant treatment were considered, it was seen that chips prepared by addition of 0.02% dried curry leaf powder or fresh banana peel into frying oil and stored under MAP in laminated pouches retained less moisture during later stages of storage. The treatments had least moisture content at 90 days of storage. Highest moisture content was recorded by untreated samples packed in LDPE (9.43%) followed by those packed in laminated pouches (8.90%). This is in accordance with the findings of Abong *et al.* (2011 a.) who had reported the same result in potato chips.

Islam and Shams-Ud-Din (2003) recommended that high density or laminated aluminum foil is suitable for long time storage of chips. Rahman and Shams-Ud-Din (2003) found that chips packed in low density polyethylene shortened the storage periods of chips.

5.2.1. b. ***Yellowness Index (Colour)***

Colour is the major quality criterion for determining the commercial quality with respect to consumer preferences and cost of the chips (Anand *et al.*, 1982). Till 30 days of storage there was no significant difference in colour between treatments in different packaging materials. Banana chips prepared by directly adding 0.02% oven dried curry leaf powder and stored under MAP in laminated pouches retained significantly highest yellowness index at 60 days (109.98) and 90 days (109.86) of storage. Fresh banana peel treated chips stored under MAP in laminated pouches also had high yellowness index (108.54) at the final stage of storage. Retention of higher yellowness may be due to the protection given by the metalised polyester in laminated packaging material and the antioxidant applied. For other samples original yellow colour of banana chips was lost and brown colour developed which was in accordance with the findings of Roopa *et al.* (2006). Gradual fading of the typical golden yellow colour of banana chips and turning to pale yellow and white colour during storage was also reported by

Ogazi (1986) who had reported that processing condition and storage condition affect the colour of chips.

5.2.1. c. *Textural Quality*

Texture is not a single attribute. It is a collective term that encompasses the structural and mechanical properties of a food and their sensory perception in the hand or mouth. Instrumental texture analysis are preferred over sensory evaluations for research because instruments reduce variations so, are more precise (Abbott *et al.*, 1997).

At the time of preparation of banana chips there was no significant difference between treatments in terms of hardness. By 30 days of storage, least hardness (6.34 N) was recorded by untreated samples packed in LDPE pouches which was on par with all treatments except fresh banana peel treated chips stored under MAP in laminated pouches (7.89 N) and untreated chips stored in laminated pouches (8.08). By 60th day of storage, least hardness (6.17 N) was recorded by 0.02% curry leaf powder treated chips packaged under MAP in laminated pouches which maintained the least hardness (4.86 N) at 90 days of storage also.

Though there was no significant difference among treatments, curry leaf powder treated chips stored under MAP in laminated pouches recorded least toughness at 60 days (2.42 Ns) as well as 90 days of storage (1.90 Ns).

Crispness is associated with large voids in the material and expansion (Winnie *et al.*, 2002).

Till 30 days of storage there was no significant difference between treatments in terms of crispness. Howarth (1994) reported that packages having high water vapour barrier can maintain crispness of the fried and dried products. MAP had low or no water vapour permeability. Banana chips prepared by adding 0.02% oven dried curry leaf powder and stored under MAP in laminated pouches retained significantly highest crispness during 60 days (5.32) and at 90 days (5.12) of storage. As crispness is one of the major factors affecting quality of banana chips, curry leaf powder treated chips can be considered better in textural properties.

5.2.2. Changes in Chemical Quality

Packaging is critical in maintaining product quality while offering protection from microbial and chemical contamination, as well as from oxygen water vapour and light (Rajkumar *et al.*, 2007). Reactions occur during frying and storage are oxidation and hydrolysis (Jia *et al.*, 2010). Free fatty acid value, peroxide value and iodine value of the stored chips were measured at fortnightly intervals.

FFA value of chips stored in each packaging material was same for treated and untreated samples till 15 days of storage. Free fatty acid value of antioxidant treated as well as untreated chips was found to be increasing irrespective of the packaging systems used. But, the rate of increase in free fatty acid value was found to be lower for chips stored under MAP in laminated pouches compared to those packed in laminated and LDPE pouches (Fig 9.). In LDPE pouches there is a high chance of oxidative rancidity in the product because of high oxygen availability in the head space (Nipawan *et al.*, 2012). Increase in free fatty acid value is also expected due to hydrolysis of oils (Babu *et al.*, 2013).

When chips stored within same packaging materials are compared, banana chips prepared by adding 0.02% curry leaf powder or 0.02% fresh banana peel into frying oil had similar and lower FFA value.

As in FFA value, peroxide value of treated and untreated samples were found to be increasing irrespective of the packaging systems used. The result is in agreement with the report of Nipawan *et al.* (2012) on fried banana snacks. But the rate of increase in peroxide value is found to be lower for chips packaged under MAP in laminated pouches compared to those packed in laminated and LDPE pouches (Fig 10.). Increase in peroxide value and rancid odour results in termination of shelf life (Babu *et al.*, 2013).

Addition of oven dried curry leaf powder to frying oil had lowered the peroxide value of chips (Table 19.) and this treatment retained a low peroxide

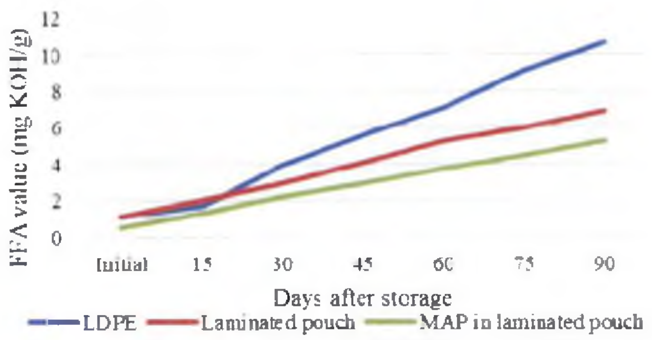


Fig 9. a. Curry leaf powder treated chips

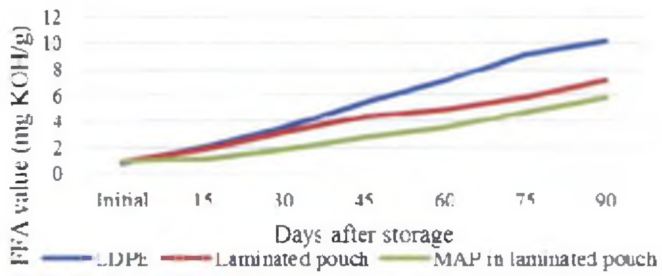


Fig 9. b. Fresh banana peel treated chips

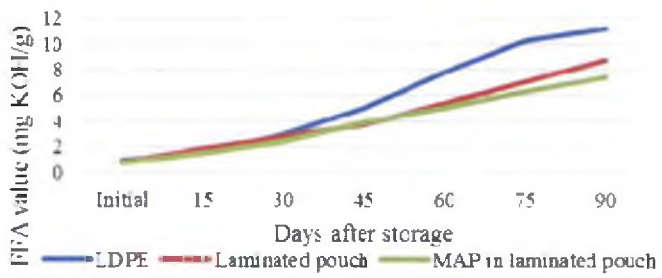


Fig 9. c. Untreated chips

Fig 9. Free fatty acid value of chips stored under different packaging systems

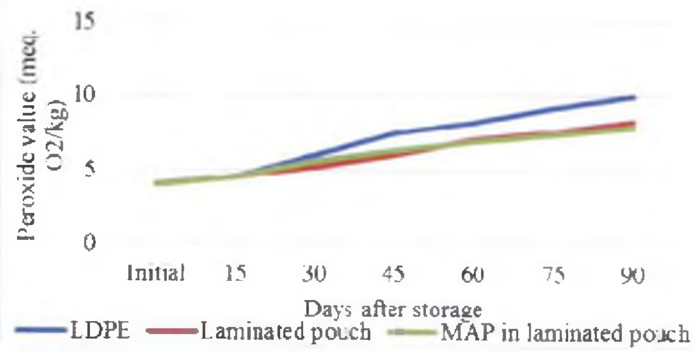


Fig 10. a. Curry leaf powder treated chips

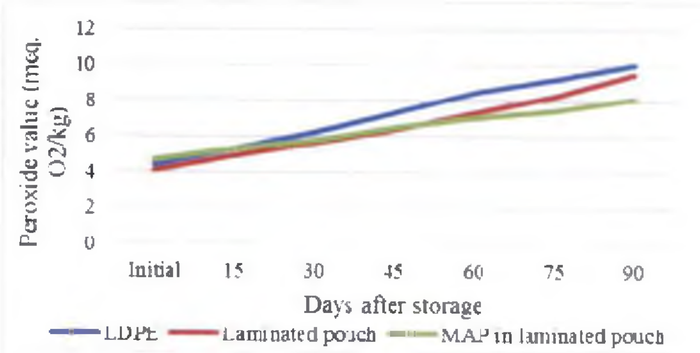


Fig 10. b. Fresh banana peel treated chips

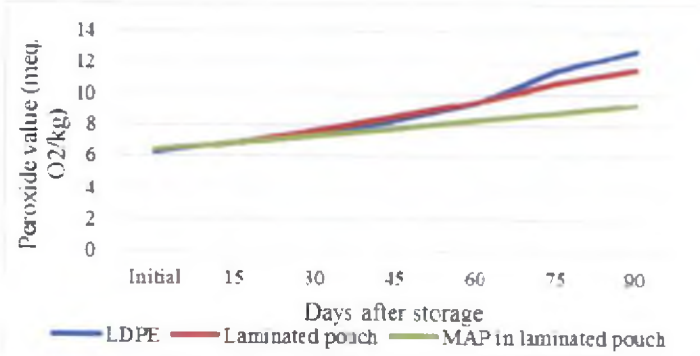


Fig 10. c. Untreated chips

Fig 10. Peroxide value of chips stored under different packaging systems value throughout the storage period. Das *et al.* (2011) reported that use of curry leaf powder inhibits the formation of free fatty acids and lipid peroxide in ground goat meat.

During the later stages of storage period, fresh banana peel and dried curry leaf powder were equally effective when antioxidant treatment and packaging materials were considered together. Banana chips prepared by adding 0.02% curry leaf powder or fresh banana peel into frying oil and stored under MAP in laminated pouches recorded a low peroxide value at final storage period of 90 days.

Addition of antioxidants in banana chips has resulted in increased iodine value. Treated banana chips had high iodine value compared to untreated chips throughout the storage period.

Compared to fresh banana peel, oven dried curry leaf powder applied banana chips had higher iodine value throughout storage period. Fresh banana peel added chips recorded iodine values of 7.11, 8.84 and 9.22 whereas curry leaf powder added chips recorded 7.96, 9.26 and 10.27 at 90 days of storage in LDPE, laminated pouches and MAP respectively. Lemmens *et al.* (2010) also reported that heating can disrupt the cell membrane leading to the release of membrane bound phytochemical, which implies higher bio accessibility.

During storage iodine value was seen decreased and the rate of decrease was low in MAP in laminated pouches compared to those packed in laminated and LDPE pouches (Fig. 11). In MAP, the vacuum removes most of the oxygen in the system diminishing oxidative reactions and preserving flavor and colour (Winnie *et al.*, 2002). Chips prepared by adding oven dried curry leaf powder to frying oil and stored under MAP in laminated pouches had high iodine value and this treatment retained a slow rate of decrease in iodine value throughout the storage period.

Total antioxidant activity is a factor which is responsible for enhanced shelf life in treated chips. Hence, chips with good shelf life should have high total antioxidant activity. Treated banana chips had high total antioxidant activity compared to untreated chips throughout the storage period. Compared to fresh

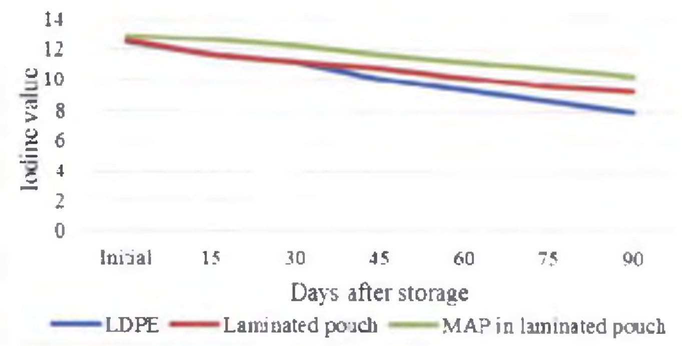


Fig 11. a. Curry leaf powder treated chips

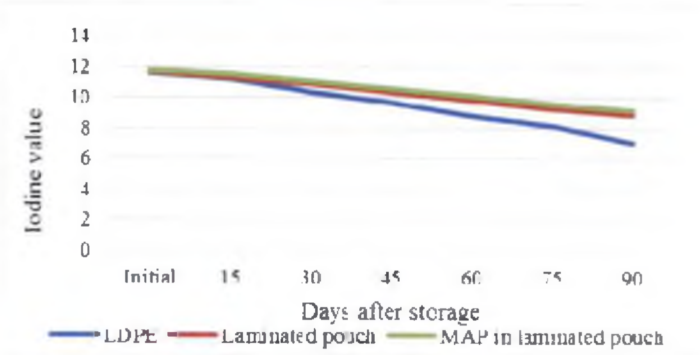


Fig 11. b. Fresh banana peel treated chips

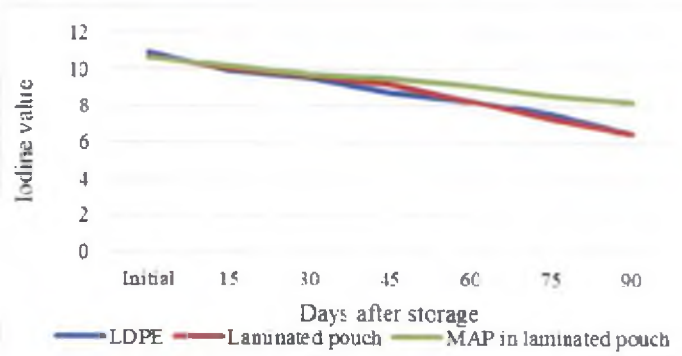


Fig 11. c. Untreated chips

Fig 11. Iodine value of chips stored under different packaging systems banana peel, oven dried curry leaf powder applied banana chips had higher total antioxidant activity throughout storage period. Higher antioxidant activity of oven dried curry leaf powder may be due to release of bound antioxidant principle during heat treatment (Sobhana and Naidu, 2000). According to Madalageri *et al.* (1996) the best drying method of curry leaves is oven drying at 50^0 C which has been adopted in the present experiment.

Total antioxidant activity of antioxidant treated as well as untreated chips was found to be decreasing irrespective of the packaging systems used. But the rate of decrease in total antioxidant activity was found to be in the order, MAP in laminated pouches < laminated pouches < LDPE pouches (Fig 12.). Metallized film used in lamination is considered to have relatively high resistance to oxygen due to its low oxygen permeability (Robertson, 1993). In MAP process, product is packaged in an atmosphere, different from that of air. MAP helps to delay the onset of product deterioration by reducing the amount of oxygen exposed to the product during the shelf life (Jayas and Jayamkondan, 2002). In the present study, oxygen is replaced with nitrogen in MAP.

Chips prepared by adding oven dried curry leaf powder to frying oil and stored under MAP in laminated pouches had high total antioxidant activity and this treatment retained a slow rate of decrease in antioxidant activity throughout the storage period. The antioxidant activity of curry leaf powder is attributed to mahanimbine, murrayanol, mahanine (Ningappa *et al.*, 2008) and koenigine (Rao *et al.*, 2007).

5.2.3. Changes in Sensory Quality

Banana chips prepared using selected antioxidants and untreated chips were stored in three different packaging materials and sensory scoring was done for three months at an interval of 15 days. Packaging does not only ensures that food contains and maintains the amount and form of the required ingredient and nutrients but also improves sensory quality and colour stability (Balev *et al.*, 2011). Proper packaging and storage of chips in appropriate conditions is therefore an important necessity if acceptability of the product in the market is to

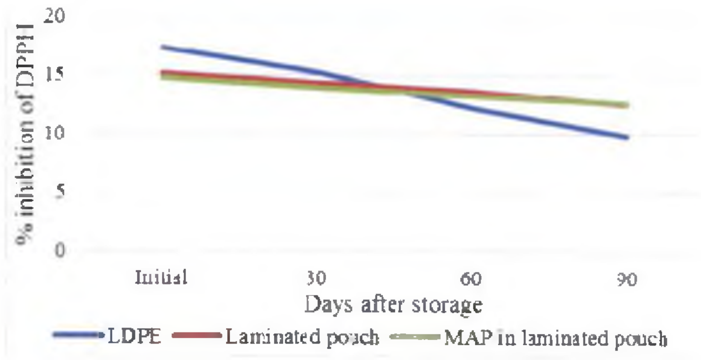


Fig 12. a. Curry leaf powder treated chips

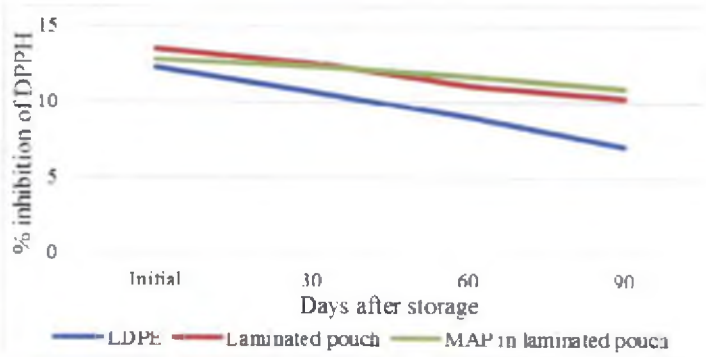


Fig 12. b. Fresh banana peel treated chips

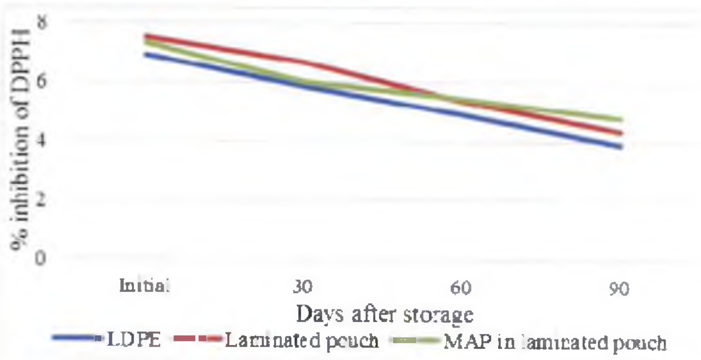


Fig 12. c. Untreated chips

Fig 12. Total antioxidant activity of chips stored under different packaging systems.

be maintained (Abong *et al.*, 2011b.). Banana chips packed in LDPE pouches recorded least mean rank values for all sensory quality attributes even if it is treated with antioxidants, indicating the importance of packaging materials.

100 gauge LDPE is the commonly used packaging material in our local market. It is the packaging material with an average of 18 g/m^2/day water vapour transmission rate and 4000 $O_2/cm^3/m^2$ oxygen transmission rate (Siracusa, 2012). As LDPE permits entry of oxygen to inside of the package, affected the sensory quality parameters of stored chips. This result is supported by the findings of Adeniji (2005) who stated that banana chips packed in transparent polythene covers developed off flavour and colour due to accelerated lipid oxidation in presence of light. This may be the reason for less acceptable quality parameters for chips stored in the transparent LDPE pouch than laminated pouch, where the chips is protected to a great extent from exterior illumination.

Treated chips, when packed in laminated pouches maintained good high sensory quality attributes throughout storage indicating the beneficial effect of adding banana peel and curry leaf powder to frying oil while preparing chips. Untreated chips failed to retain the sensory quality attributes even if they are packed in laminated pouches. It is generally established that antioxidants function as oxygen interceptors in the oxidative process thereby breaking the chain reaction that perpetuates the process and enhances shelf life of the product.

Treated as well as untreated chips could maintain all sensory quality attributes when it is stored under MAP in laminated pouches for 90 days. Superior sensory quality attributes viz., appearance (75.60), colour (73.85), flavour (77.40), taste (81.95), texture (72.55) and overall acceptability (79.50) were recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder and stored under MAP in laminated pouches. Colour of untreated chips stored under MAP in laminated pouches was seen faded indicating a lower sensory score at 90 days after storage compared to initial colour. The decrease in scores of sensory attributes indicates that consumers are able to detect changes that occur in stored chips. The main factor is light which gives a pale yellow colour to chips during storage due to oxidation. Compared to chips stored in

LDPE and laminated pouches, MAP recorded highest overall acceptability irrespective of the treatments applied (Fig 13.). Since MAP could scavenge oxygen present inside the package oxidation reactions was arrested and the product could maintain its quality during storage.

Based on superior physical, chemical and sensory quality parameters, it can be concluded that preparing banana chips by adding 0.02% oven dried curry leaf powder to frying oil and storing under MAP in laminated pouches could ensure a shelf life of three months.

5.3. DEVELOPMENT OF FLAVOURED BANANA CHIPS

5.3.1. Organoleptic Evaluation of Flavoured Chips

Flavoured banana chips were developed by adding different types of flavour imparting substances like garlic, black pepper, curry leaves and coriander leaves in two different forms at two different concentrations. The developed flavoured chips were subjected to preliminary evaluation by conducting organoleptic studies.

Banana chips prepared by directly adding 2% oven dried garlic powder recorded highest mean rank value for appearance (31.05), flavour (34.40) and taste (34.95). The active substance allicin (diallyl thiosulfate) is responsible for the typical pungent smell (Macpherson *et al.*, 2005) which at high concentration of 2% impart flavor to chips thereby enhancing mean rank score.

Though no significant difference existed for appearance, colour and texture, banana chips prepared by direct addition of 2% oven dried black pepper powder recorded highest mean rank value for flavour (35.5) and taste (35.5). Tarko *et al.* (2010) reported that black pepper flavoured apple chips was accepted only by a very narrow group of consumers preferring spicy food.

Banana chips prepared after direct addition of 2% oven dried curry leaf powder into frying oil recorded highest mean rank values for appearance (30.80), colour (29.80), flavour (28.70) and taste (29.45). Banana chips prepared by directly adding 2% oven dried coriander leaf powder to frying oil recorded highest mean rank values for appearance (30.60), flavour (35.50) and taste (35.50). Flavour and colour of chips treated with fresh coriander/curry leaves was not good as that of chips with corresponding leaf powders. During drying chlorophyll converted to pheophytins causing a colour change from dark green to olive brown which is undesirable to the consumer. Alibas (2006) reported that blanching prior to frying could greatly reduce chlorophyll loss.

When overall acceptability of all flavoured banana chips was analysed (Fig 14.) it could be noted that addition of a higher concentration is needed for imparting superior sensory qualities and oven dried powdered form was superior to its fresh form. Here, all flavour imparting substances are providing good organoleptic characteristics to banana chips in its oven dried powdered form only at 2% concentration.

5.3.2. Consumer Acceptability Study of Selected Flavoured Chips

Today's consumers are discerning, demanding and more knowledgeable about food and expect products which are safe, good value and of high sensory quality. Therefore, knowing consumer preferences and perceptions of the sensory characteristics of food products is very important to food manufacturers and retailers alike (FIF, 2005). Without appropriate sensory analysis there is a high risk of market failure. Sensory analysis is frequently considered as a requirement before product launch (Arazi and Kilcast, 2001).

Curry leaf powder has already been accepted for inclusion in several food preparations. Khatoon *et al.* (2011) reported that addition of 3% dehydrated curry leaf to lemon rice and uttapam and 4% addition to mathri and idli scored best for organoleptic characteristics. Shanthala and Prakash (2005) reported that sensory scores decreased as level of increase of curry leaf powder increased in seasoned potatoes. But in the present study, curry leaf powder added to oil at 2% adhered to the banana slices and resulted in impared appearance even though it scored high for flavour (7.40) (Plate 13.). Sensory quality depends on food characteristics and also on the consumers (Costell, 2002) which might have resulted in varied acceptance.

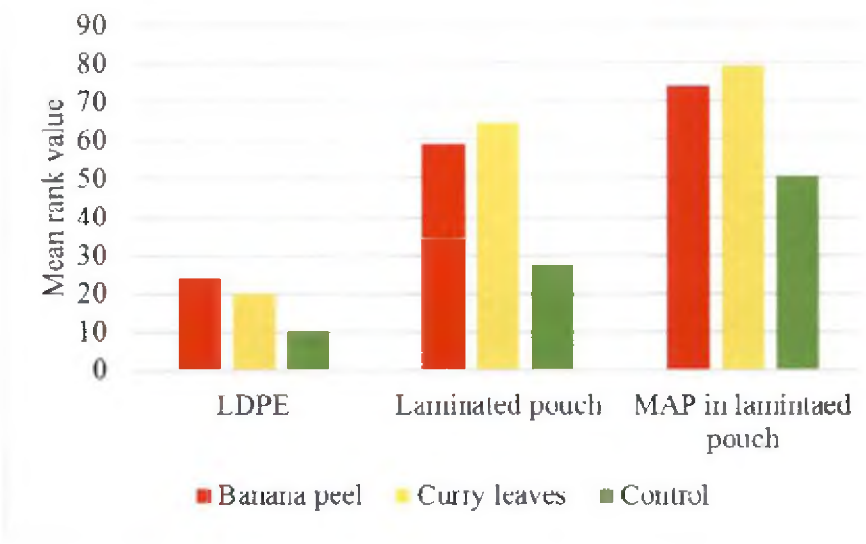


Fig 13. Overall acceptability of treated chips during storage

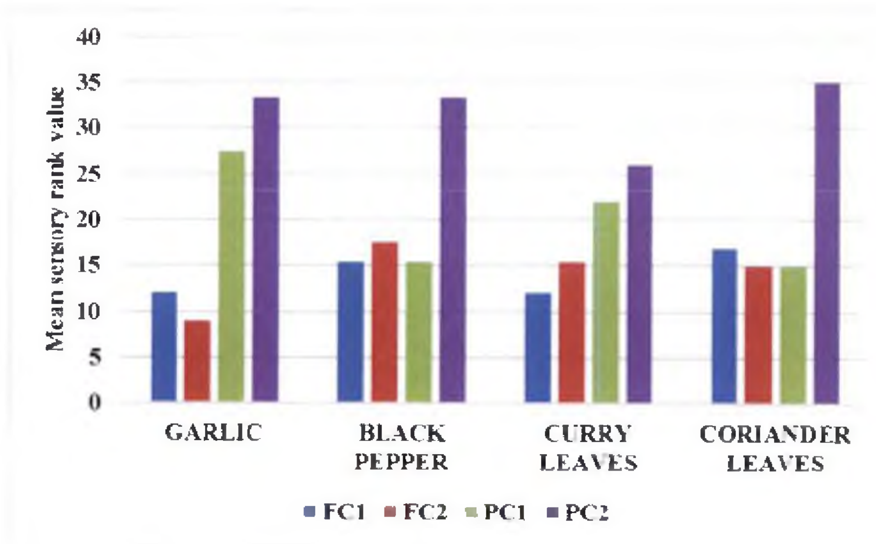


Fig 14. Overall acceptability of flavoured banana chips

Plate 13. Adherence of curry leaf powder to banana chips

Garlic flavoured banana chips recorded highest mean scores for all the organoleptic characteristics. Chips prepared by adding 2% garlic powder scored highest mean rank for appearance (8.10), colour (7.90), flavour (9.10), taste (9.00) and crispness (8.30). Ngarmsak *et al.* (2002) showed that garlic was the most preferred herb in snacks.

Star diagram/ star chart (Fig. 15.) allows a rage of food products, intensity of its sensory attributes to be recorded. Hence, star diagram was plotted to evaluate differences in similar products and show new opportunities for product development. Higher the mean rank score higher will be intensity of positive attributes and it will be at maximum distance from the central point. The garlic flavoured chips, produced by the direct addition of 2% oven dried garlic powder to frying oil, which showed maximum acceptance, had all selected sensory attributes with maximum intensity. The developed product has to be further tested in a large population before market launching.

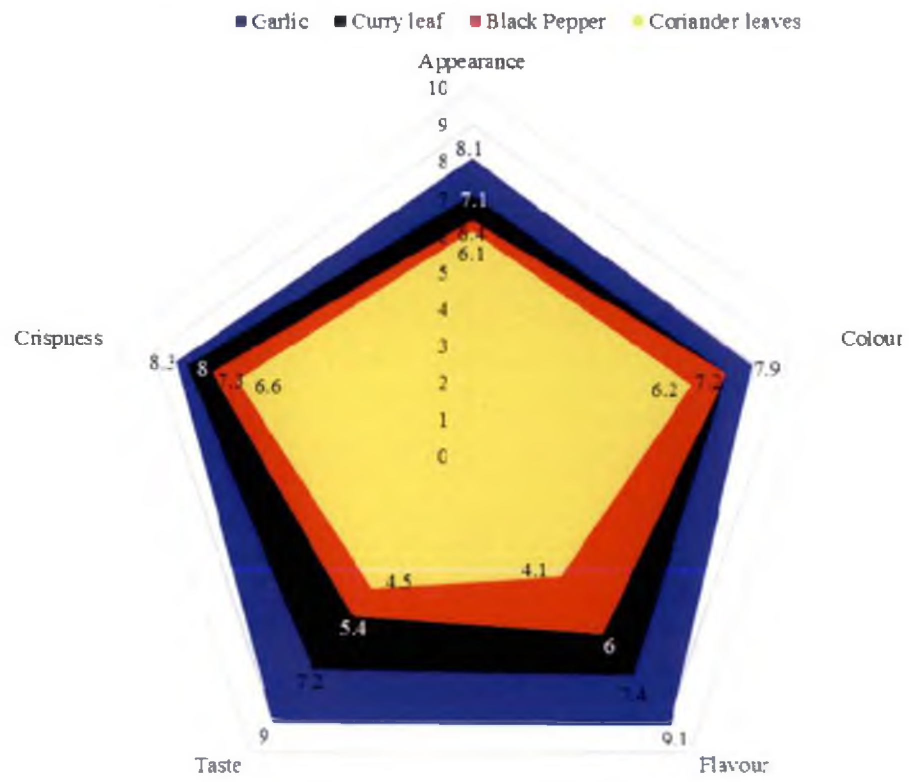


Fig 15. Sensory quality attributes of selected flavoured chips

Summary

6. SUMMARY

The present investigation entitled "Development of Nendran banana chips with enhanced shelf life and quality" was carried out in the Department of Processing Technology, College of Agriculture, Vellayani during the period 2012-2014 to evaluate and compare the effect of natural antioxidants in delaying rancidity of banana chips during storage and to explore the possibility of developing flavoured chips with extended shelf life. The study was carried out as three parts.

1. Effect of antioxidants on quality of banana chips.
2. Storage potential of treated banana chips.
3. Development of flavoured banana chips.

The major findings are summarized as follows

Nendran banana chips were prepared in unrefined coconut oil by incorporating two set of antioxidants viz., processing wastes (banana peel, potato peel, watermelon and cucumber peel) and flavour imparting substances (garlic, black pepper, curry leaf and coriander leaves) in fresh and oven dried powdered form by two different methods viz., pre-soaking slices in antioxidants before frying and direct addition of antioxidants in oil. Two experiments with 32 treatments each, were conducted separately with two set of antioxidants.

Good quality banana chips should have low moisture content, oil uptake and shrinkage with high integrity. Chemical quality parameters like free fatty acid value and peroxide value should be low and iodine value should be high for enhanced shelf life of these deep fried product. Yield is an essential factor to be considered along with these quality parameters.

Analysis of physical quality attributes of chips prepared by adding antioxidant rich processing waste revealed that, addition of 0.02% fresh banana peel into frying oil resulted in low moisture content (6.45%), oil uptake (30.65%) and shrinkage (21.00%) with a low yield (65.60%) and high integrity (84.45%). Banana chips prepared from slices presoaked in 0.02% oven dried banana peel powder had highest yield (77.10%), higher oil uptake (38.05%) and maximum moisture content (9.00%).

On chemical analysis, the lowest FFA value (3.08 mg KOH/g), peroxide value (4.70 meq. O_2 / kg) and highest iodine value (8.76) was recorded by banana chips prepared by direct addition of 0.02% fresh banana peel into frying oil indicating its superiority.

Presoaking slices in antioxidant rich processing waste, produced chips with least chemical quality attributes. The highest FFA value was recorded by banana chips prepared from slices presoaked in 0.01% oven dried cucumber peel powder (12.34 mg KOH/g) and those soaked in 0.02% oven dried water melon peel powder recorded the highest peroxide value (9.40 meq. O_2 / kg). Chips prepared after presoaking slices in 0.01% of fresh potato peel recorded lowest iodine value (5.78).

Chips with highest physical and chemical quality attributes were supported with high sensory scores too. Chips prepared by adding 0.02% fresh banana peel to frying oil recorded highest mean rank value for colour (223.50), taste (266.90), texture (248.80) and overall acceptability (268.10). Cucumber peel, potato peel and watermelon peel were inferior in providing antioxidant principles of chips and chips produced using those peels were poor in physical, chemical and sensory parameters.

Chips prepared by adding antioxidant rich flavor imparting substances viz., garlic, black pepper, curry leaf and coriander leaves were subjected to physical, chemical and sensory quality analysis.

Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder to frying oil recorded the least moisture content (5.30%), oil uptake (31.40%) and shrinkage (20.95%), hence with the lowest yield (64.15%) and high integrity (85.90%).

Banana chips prepared from slices presoaked in 0.01% fresh garlic recorded the highest moisture content (8.25%), yield (75.40%) and higher oil uptake (40.20%). Maximum oil uptake (42.05%) was recorded by banana chips prepared from slices presoaked with 0.01% oven dried coriander leaf powder.

Negative correlation existed between yield and physical quality parameters like moisture content and oil uptake. Presoaking banana slices in any antioxidant solution whether processing waste or flavour imparting substances resulted in an increased moisture absorption which increased the chance for more oil absorption and hence higher yield. The superiority of direct application of antioxidants in oil was observed in both antioxidant types.

Banana chips prepared by direct addition of 0.02% oven dried curry leaf powder into frying oil had low FFA value (3.02 mg KOH/g), peroxide value (6.50 meq. O_2 / kg) and highest iodine value (6.73) indicating its superiority over other flavor imparting substances tested and method of application tried.

Banana chips prepared by direct addition of 0.02% oven dried coriander leaf powder recorded the lowest FFA value (2.52 mg KOH/g) and peroxide value (6.20 meq. O_2 / kg). Slices presoaked in 0.01% oven dried coriander leaf powder recorded the highest peroxide value (9.30 meq. O_2 / kg) and slices presoaked in 0.01% fresh garlic recorded the lowest iodine value (3.32).

Chips prepared by adding 0.02% oven dried curry leaf powder to frying oil scored highest mean rank value for appearance (281.20), flavour (284.10), colour (278.25), taste (282.80), texture (269.00) and over all acceptability (291.60).

Banana chips prepared by slices presoaked in 0.01% fresh and oven dried curry leaf powder as well as 0.02% fresh coriander leaves recorded lowest mean rank value for appearance (122.40). The lowest mean rank value for flavour (112.90) was recorded by banana chips prepared from slices presoaked in 0.02% fresh garlic. The lowest mean rank value for taste (114.50) was recorded by banana chips prepared from slices presoaked in 0.01% fresh curry leaves. The lowest mean rank value for texture (123.95) was recorded by banana chips prepared from slices presoaked in 0.02% oven dried black pepper powder. Presoaking of slices resulted in chips with low sensory qualities.

Based on superior physical, chemical and sensory quality parameters addition of 0.02% fresh banana peel and oven dried curry leaf powder to frying oil at smoke point were selected as the best treatments from processing waste and flavour imparting substances respectively for further storage study.

Chips prepared by direct addition of 0.02% curry leaf powder and fresh banana peel as well as untreated samples were stored under three different packaging systems viz., LDPE pouch, laminated pouch and MAP in laminated pouch for three months and evaluated for moisture, colour, texture, chemical and sensory quality parameters.

Physical, chemical and sensory quality parameters of all chips decreased during storage. Moisture content of stored chips increased in all treatments irrespective of antioxidant treatments and packaging materials. But, the rate of increase was lower for chips stored under MAP in laminated pouches compared to those stored in laminated and LDPE pouches. When the moisture content of treated and untreated chips were compared, the treated chips had a lower moisture content compared to untreated chips in all packaging materials throughout the storage period.

When the combined effect of packaging material and antioxidant treatment were considered, chips prepared by addition of 0.02% dried curry leaf powder or fresh banana peel into frying oil and stored under MAP in laminated pouches retained less moisture during later stages of storage. The treatments had least moisture content at 90 days of storage. Highest moisture content (9.43%) was recorded by untreated samples packed in LDPE pouches.

Instrumental colour (yellowness index) analysis at 90 days of storage showed the highest yellowness index (109.86) for banana chips prepared by adding 0.02% oven dried curry leaf powder and stored under MAP in laminated pouches due to the protection given by the lamination and the antioxidant applied.

When texture was recorded in terms of hardness, toughness and crispness least hardness (4.86 N), toughness (1.90 Ns) and highest crispness (5.12) was recorded by 0.02% curry leaf powder treated chips packaged under MAP in laminated pouches on 90 days of storage.

Free fatty acid value and peroxide value of treated and untreated chips were increased and iodine value and total antioxidant activity decreased during storage irrespective of the packaging systems used. But, the rate of change was lower in chips stored under MAP in laminated pouches compared to those packed in laminated and LDPE pouches.

When chips stored within same packaging materials are compared, banana chips prepared by adding 0.02% curry leaf powder or 0.02% fresh banana peel into frying oil had similar and lower FFA value and peroxide value at final storage period.

Treated banana chips had high iodine value and total antioxidant activity compared to untreated chips throughout the storage period. Compared to fresh banana peel, oven dried curry leaf powder applied banana chips had higher iodine value throughout storage period.

Chips prepared by adding oven dried curry leaf powder to frying oil and stored under MAP in laminated pouches had high total antioxidant activity and this treatment retained a slow rate of decrease in antioxidant activity throughout the storage period.

Banana chips stored in LDPE pouches recorded least mean rank values for all sensory quality attributes even if it is treated with antioxidants.

Treated chips, when packed in laminated pouches maintained good high sensory quality attributes throughout storage indicating the beneficial effect of adding banana peel and curry leaf powder to frying oil while preparing chips. Untreated chips failed to retain the sensory quality attributes even if they are packed in laminated pouches.

Treated as well as untreated chips could maintain all sensory quality attributes when it is stored under MAP in laminated pouches for 90 days. Superior sensory quality attributes viz., appearance (75.60), colour (73.85), flavour (77.40), taste (81.95), texture (72.55) and overall acceptability (79.50) were recorded by banana chips prepared after adding 0.02% oven dried curry leaf powder and stored under MAP in laminated pouches.

Based on superior physical, chemical and sensory quality parameters, it was concluded that preparing banana chips by adding 0.02% oven dried curry leaf powder to frying oil and storing under MAP in laminated pouches could ensure a shelf life of three months.

The possibility of development of flavoured banana chips was explored by adding different flavor imparting substances like garlic, black pepper, curry leaves and coriander leaves in two different forms at two different concentrations and they were subjected to preliminary evaluation by organoleptic studies.

Addition of 2% concentration was found necessary for imparting superior sensory qualities and oven dried powdered form was superior to its fresh form in all flavour imparting substances tried. On further sensory evaluation, 2% garlic powder added chips was selected as the best flavoured chips by the sensory panel which was again proved by plotting star diagram. It was having highest mean rank for appearance (8.10), colour (7.90), flavour (9.10), taste (9.00) and crispness (8.30).

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Abstract

Development of Nendran Banana Chips with Enhanced Shelf Life and Quality

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ABSTRACT

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Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PROCESSING TECHNOLOGY
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ABSTRACT

The present investigation entitled "Development of Nendran banana chips with enhanced shelf life and quality" was conducted at Department of Processing Technology, College of Agriculture, Vellayani, with the objective to evaluate and compare the effect of natural antioxidants in delaying rancidity of banana chips during storage and to explore the possibility of developing flavoured chips.

Nendran banana chips were prepared in unrefined coconut oil by incorporating two types of antioxidants viz., processing waste and flavour imparting substances in fresh and dried forms at 0.01 and 0.02 % concentrations, either by presoaking slices in antioxidant solution before frying or by directly adding to frying oil. The prepared chips were analysed for physical, chemical and sensory quality parameters.

Banana chips prepared by addition of 0.02% fresh banana peel to frying oil recorded the least moisture (6.45%), oil uptake (30.65%), peroxide value (4.70 meq. O_2/ kg) and free fatty acid (FFA) value (3.08 mg KOH/ g) along with highest integrity (84.45%) and iodine value (8.76) indicating superior quality. Of all the flavor imparting substances tried, chips prepared by adding 0.02% dried curry leaf powder to frying oil had lowest moisture (5.30%), oil uptake (31.40%) peroxide (6.50 meq. O_2/ kg) and FFA value (3.02 mg KOH/ g) along with highest integrity (85.90%) and iodine value (6.73). Both these treatments recorded highest sensory parameters too, hence selected for further storage study.

Banana chips prepared using fresh banana peel and dried curry leaf powder were stored in low density polyethylene pouches, tri-layered laminated pouches and under modified atmospheric packaging (MAP) in laminated pouches for three months to evaluate the shelf stability. Chips prepared with 0.02% dried curry leaf powder and packed under MAP in laminated pouches showed low moisture (6.90%), least hardness (4.86 N), toughness (1.90 Ns), FFA value (5.24 mg KOH/g), peroxide value (7.87 meq. O_2/ kg), highest iodine value (10.27), yellowness index (109.86), crispness (5.12) and higher mean rank value for

sensory parameters throughout storage period. Highest antioxidant activity (12.61 ± 1.31 %) was also recorded by this treatment.

When the possibility of development of flavoured banana chips was explored, chips prepared by addition of 2% dried garlic powder was acceptable to the sensory panel.

The study revealed that preparation of Nendran banana chips by addition of 0.02% dried curry leaf powder into frying oil and storing under modified atmospheric packaging system in laminated pouches can ensure a shelf life of three months.

സംഗ്രഹം

കേരളത്തിൽ ഏറെ പ്രചാരമുള്ള ഏത്തക്കാ ഉപ്പേരിയുടെ പ്രധാനപ്രശ്നമായ 'കാറൽ' അഥവാ 'കനച്ചുപോകൽ' തടഞ്ഞ് ഗുണമേൻമയും സംഭരണശേഷിയുമുള്ള ഉത്പന്നം വികസിപ്പിച്ചെടുക്കുക എന്ന ഉദ്ദേശത്തോടെ 2012–' 14 വർഷത്തിൽ പ്രോസസിംഗ് ടെക്നോളജി വിഭാഗത്തിൽ നടത്തിയ പരീക്ഷണമാണ് "ഡെവലപ്മെന്റ് ഓഫ് നേന്ത്രൻ ബനാന ചിപ്സ് വിത്ത് എൻഹാൻസഡ് ഷെൽഫ് ലൈഫ് ആന്റ് ക്വാളിറ്റി."

ഉപ്പേരിയിലെ എണ്ണയിലടങ്ങിയ അപൂരിത കൊഴുപ്പുകൾ ഓക്സിജനുമായി ചേർന്ന് അസ്വീകാര്യമായ മണവും സ്വാദും ഉണ്ടാക്കുന്നതാണ് കാറൽ. ഈ ഓക്സീകരണം തടയാൻ കഴിവുള്ള വിവിധ പഴം/പച്ചക്കറികളുടെ തൊലി, സുഗന്ധവ്യഞ്ജനങ്ങൾ എന്നിങ്ങനെ രണ്ട് തരം പ്രകൃതിജന്യ ആന്റിഓക്സിഡന്റുകളാണ് ഈ ഗവേഷണത്തിനായി ഉപയോഗിച്ചത്.

പ്രകൃതിജന്യ ആന്റിഓക്സിഡന്റുകൾ അടങ്ങിയ പദാർത്ഥങ്ങൾ പച്ചയ്ക്ക് ചെറിയ കഷ്ണങ്ങളാക്കിയോ ഉണക്കിപ്പൊടിച്ചോ 0.01% അല്ലെങ്കിൽ 0.02% വീര്യത്തിൽ നേരിട്ട് വറുക്കാനുപയോഗിക്കുന്ന എണ്ണയിലിടുകയോ, അല്ലെങ്കിൽ ഏത്തയ്ക്ക കഷ്ണങ്ങൾ ആന്റിഓക്സിഡന്റ് ലായനിയിൽ ഇട്ടശേഷം വറുത്തെടുക്കുകയോ ആണ് ചെയ്തത്.

0.02% പച്ച ഏത്തയ്ക്കതൊലി, എണ്ണയിൽ ചേർത്തുണ്ടാക്കിയ ഉപ്പേരിയിൽ കുറഞ്ഞ ജലാംശം (6.45%), എണ്ണയുടെ അംശം (30.65%), പെറോക്സൈഡ് മൂല്യം (4.70 m eq.O_2 /Kg), ഫ്രീ ഫാറ്റി ആസിഡ് മൂല്യം (3.08 mg KOH/g) ഉയർന്ന അയഡിൻ മൂല്യം (8.78) എന്നിവ രേഖപ്പെടുത്തുകയുണ്ടായി.

സുഗന്ധവ്യഞ്ജനങ്ങളിൽ, 0.02%ഉണക്കിയ കറിവേപ്പിലപൊടി എണ്ണയിൽ ചേർത്ത് പാകം ചെയ്ത ഉപ്പേരിയിലാണ് കുറഞ്ഞ ജലാംശം (5.30%), എണ്ണയുടെ അംശം (31.40%) പെറോക്സൈഡ് മൂല്യം (6.50 m eq.O_2 /Kg), ഫ്രീ ഫാറ്റി ആസിഡ് മൂല്യം (3.02 mg KOH/g) ഉയർന്ന അയഡിൻ മൂല്യം (6.73) എന്നിവ രേഖപ്പെടുത്തിയത്.

കുറഞ്ഞ ജലാംശം, എണ്ണയുടെ അംശം, പെറോക്സൈഡ് മൂല്യം, ഫ്രീ ഫാറ്റി ആസിഡ് മൂല്യം, ഉയർന്ന അയഡിൻ മൂല്യം എന്നിവ ഗുണമേൻമയുള്ള ഉപ്പേരിയുടെ ഘടകങ്ങളായി കണക്കാക്കിയിരിക്കുന്നതിനാൽ, ഇവ രേഖപ്പെടുത്തിയ 0.02% പച്ച ഏത്തയ്ക്കാ തൊലിയും ഉണക്കിയ കറിവേപ്പിലപ്പൊടിയും ചേർത്ത ഉപ്പേരികൾ തുടർന്നുള്ള പഠനത്തിനായി തിരഞ്ഞെടുത്ത് മൂന്നു തരം പാക്കറ്റുകളിലാക്കി [ലോ ഡെൻസിറ്റി പോളി എത്തിലിൻ, മൂന്ന് അടുക്കുകളുള്ള ലാമിനേറ്റഡ് കവർ, ലാമിനേറ്റഡ് കവറുകളിൽ നൈട്രജൻ വാതകം നിറച്ചുള്ള സംഭരണം] മൂന്ന് മാസം സംഭരിച്ച് വച്ച വിവിധ ഗുണമേന്മാഘടകങ്ങൾ പരിശോധിച്ചു.

0.02% ഉണക്കിപൊടിച്ച കറിവേപ്പില, ഏത്തയ്ക്കാ കഷണങ്ങൾക്കൊപ്പം എണ്ണയിൽ ചേർത്ത് വറുത്തുണ്ടാക്കിയ ഉപ്പേരി; നൈട്രജൻവാതകം നിറച്ച ലാമിനേറ്റഡ് കവറുകളിൽ സംഭരിച്ചുവച്ചപ്പോൾ അവയിൽ കുറഞ്ഞജലാംശം (6.90%), കടുപ്പം [ഹാർഡ്നെസ്സ് (4.86), ടഫ്നസ്സ് (1.90)], ഫ്രീ ഫാറ്റി ആസിഡ് മൂല്യം (10.27 mg KOH/g) പെറോക്സൈഡ്മൂല്യം (7.87 m eq.O_2 /Kg), ഉയർന്ന അയഡിൻ മൂല്യം (10.27), നല്ല മഞ്ഞ നിറം (109.86), ക്രിസ്പ്നസ്സ് (5.12) എന്നിവ രേഖപ്പെടുത്തി.

2 %ഉണക്കിപൊടിച്ച വെളുത്തുള്ളി ഏത്തയ്ക്കാ കഷ്ണങ്ങൾക്കൊപ്പം വെളിച്ചെണ്ണയിൽ ചേർത്തു കൊടുത്തുണ്ടാക്കിയ ഉപ്പേരിയാണ് മണമുള്ള ഉപ്പേരിയിനങ്ങളിൽ ഉപഭോക്താക്കൾക്ക് ഏറ്റവും സ്വീകാര്യമായത്.

ചുരുക്കത്തിൽ 0.02% ഉണക്കിപൊടിച്ച കറിവേപ്പില വെളിച്ചെണ്ണയിൽ ചേർത്തുണ്ടാക്കിയ ഏത്തയ്ക്ക ഉപ്പേരി, നൈട്രജൻ വാതകം നിറച്ച ലാമിനേറ്റഡ് കവറുകളിൽ സൂക്ഷിച്ചാൽ മൂന്നുമാസംവരെ കാറലില്ലാതെ സംഭരിച്ചു വയ്ക്കാനാകും എന്ന സാങ്കേതിക വിദ്യ ഈ ഗവേഷണം വഴി വികസിപ്പിച്ചെടുത്തു.

Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Processing Technology

Title : Development of Nendran banana chips with enhanced shelf life and quality

PHT-02-00-01-2012 ACV (17) KAU-PG

Score card for assessing the organoleptic qualities of banana chips

Sample : Banana chips

Instructions: You are given a set of samples. Evaluate them and give scores for each criteria

Criteria	Samples							
	1	2	3	4	5	6	7	8
Appearance Breakage-B Adherence of added antioxidants- AP								
Colour Colour of.added materials if any								
Flavour Off flavor if any								
Taste – Rancid/Oily								
Texture Leathery/Crispy								
Overall acceptability								

<u>Score</u>

Like extremely - 9

Like very much - 8

Like moderately - 7

Like slightly - 6

Neither like nor dislike - 5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much - 2

Dislike extremely - 1

Name:

Signature & date:

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Processing Technology

Title : Development of Nendran banana chips with enhanced shelf life and quality

PHT-02-00-01-2012 ACV (17) KAU-PG

Score card for assessing the organoleptic qualities of flavoured banana chips

Sample : Banana chips

Instructions: You are given four chips samples. Evaluate them and give scores for each criteria

Criteria	Samples				Whether incorporation of substances affect the
	1	2	3	4	
Appearance					appearance negatively
Colour					expected colour of chips
Flavour					Flavour of added substance prominent/negligible
Taste					Of taste if any
Crispness					Crispy/leathery

Score

Like extremely - 9

Like very much - 8

Like moderately - 7

Like slightly - 6

Neither like nor dislike - 5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much - 2

Dislike extremely - 1

Name:

Signature & date:

APPENDIX III

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Processing Technology

Title: Development of Nendran banana chips with enhanced shelf life and quality

PHT-02-00-01-2012 ACV (17) KAU-PG

Sample : Banana chips

Score card for selecting the best flavoured banana chips

- You are given four different chips samples
- Evaluate them for different organoleptic attributes listed below
- Assign scores from 1 to 10 based on pleasurable and unpleasurable experiences

Criteria	Samples			
	1	2	3	4
Appearance				
Colour				
Flavour				
Taste				
Crispness				

<u>Score</u>

Bad	-	1 - 2
Poor	-	3 - 4
Fair	-	5 - 6
Good	-	7 - 8
Excellent	-	9 -10

Name:

Signature & date:

APPENDIX IV

COST OF PRODUCTION OF ANTIOXIDANT TREATED CHIPS

Items	Market price	Quantity	Cost(Rs.)	
			Curry leaf treated chips	Garlic flavoured chips
Raw banana	Rs.33/kg	3 kg	100.00	100.00
Coconut oil	Rs.80/kg	4 kg	320.00	320.00
Turmeric powder	Rs.32/50 g	3.00 g	5.00	5.00
Salt	Rs.15 / kg	14g	0.25	0.25
Labour			10.00	10.00
Overhead expense			10.00	10.00
Antioxidants	-	-	1.00	15.00
Laminated pouch	Rs.1/ pouch	-	2.00	2.00
Nitrogen filling	Rs.5/ pouch	-	5.00	5.00
Miscellaneous including dehydration		-	2.00	3.00
Total			**455.25**	**470.25**