EFFECT OF ANTIOXIDANTS AND PACKAGING IN CONTROLLING RANCIDITY OF BANANA CHIPS DURING STORAGE

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DECLARATION

I hereby declare that this thesis entitled **"Effect of antioxidants and packaging in controlling rancidity of banana chips during storage"** 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 of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Effect of antioxidants and packaging in controlling rancidity of banana chips during storage"** is a record of research work done independently by Ms.Adrika, B.V. (2009-12-101) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

The production and marketing of banana chips is a wide spread cottage scale industry in Kerala. Banana chips fried in coconut oil is a product of high demand due to its characteristic flavour and taste.

Deep-fried banana chips may potentially be used in intervention programmes to combat micronutrient deficiencies, by virtue of their iron, zinc and total carotenoid content. An average serving of 45 g chips per day provide 14.6 and 20.1% zinc and 31.1 and 23.0% iron to adult male and female, respectively. One of the major problems faced by the processors in storage of banana chips is rancidity; which imparts an off flavor to the product resulting in poor acceptability.

Oxidative rancidity in oils occurs when heat, metals or other catalysts cause unsaturated oil molecules to convert to free radicals. These free radicals are easily oxidized to yield hydroperoxides and organic compounds, such as aldehydes, ketones, or acids which give rise to the undesirable odours and flavours, characteristic of rancid fats. Oxidation of oils modifies their organoleptic properties and affecting the shelf life of the product. It results in the loss of nutritional value of food as well as changes in colour, texture, sensory and other physiological properties. The products of lipid oxidation are known to be health hazardous since they are associated with ageing, membrane damage, heart disease and cancer.

The addition of antioxidants is effective in retarding the oxidation of lipids and lipid containing foods. Even though synthetic antioxidants like Butylated Hydroxy Anisole (BHA), Butylated Hydroxy Toluene (BHT) & Tertiary Butyl Hydro Quinone (TBHQ) are commonly used in food, toxicological effects have been reported in different species and these are banned in some countries. These compounds may be implicated in many health risks, including carcinogenesis. Therefore, the most powerful synthetic antioxidant TBHQ is not allowed for food application in Japan, Canada and Europe. Similarly, BHA has also been removed from the Generally Recognized As Safe (GRAS) list of compounds.

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 extracts from plant species which are seen to possess antioxidant properties. Such research is in the main prompted by the reported possibility of synthetic antioxidants having adverse health effects on humans exposed to them.

The present investigation "Effect of antioxidants and packaging in controlling rancidity of banana chips during storage" was carried out with the following objectives

1. To evaluate and compare the effect of anti oxidants and packaging materials on the rancidity problem of banana chips.
2. To delay the onset of oxidation during storage.
3. To enhance shelf life of packed product.

Review of literature

2. REVIEW OF LITERATURE

The present study focus on the effect of antioxidants and packaging in controlling rancidity of banana chips during storage. This chapter describes the review of related research and development activities done in the past few years.

Since plantain chips are snacks, they can be consumed in between meals as much as desired, which could hitherto make provision for substantial amount of micronutrient in the diet. Deep-fried plantain and banana chips may potentially be used in intervention programmes to combat micronutrient deficiencies, by virtue of their iron, zinc and total carotenoid content. Banana chips produced from some improved varieties contain appreciable levels of iron, zinc and total carotenoids. An average serving of 45 g chips per day from banana high yielding varieties provide 14.6 and 20.1% zinc and 31.1 and 23.0% iron to adult male and female, respectively (Adeniji and Tenkouano, 2007). Banana chips can contribute 2.61 retinol equivalents (RE) daily, consumed based on Recommended Daily Dietary Allowances.

2.1. RANCIDITY

The word rancid is derived from the Latin word "*rancidus*" which means stinking. Any food can technically become rancid and the term particularly applies to oils. Oils can be particularly susceptible to rancidity because of their chemistry which makes them susceptible to oxygen damage. Oxidative rancidity in oils occurs when heat, metals or other catalysts cause unsaturated oil molecules to convert to free radicals. These free radicals are easily oxidized to hydroperoxides and organic compounds, such as aldehydes, ketones, or acids which give rise to the undesirable odors and flavors, characteristic of rancid fats (Eastman Chemical Company, 2001).

The products of lipid oxidation are known to be health hazardous since they are associated with ageing, membrane damage, heart disease and cancer. The addition of antioxidants is effective in retarding the oxidation of lipids and lipid containing foods (Suja *et al.* 2004).

Food lipids undergo a variety of chemical reactions such as accelerated oxidation, thermolysis, and polymerization under heat exposure (Warner, 2002). Oxidation of oils modifies their organoleptic properties and affecting the shelf life of the product. It results in the loss of nutritional value of food as well as changes in colour, texture, sensory and other physiological properties (Cheman & Tan, 1999). Due to these changes, consumers do not accept oxidized products and industries suffer from economic losses. The oil industry has to pay special attention in this context, as oils, fats and fatty foods suffer stability problems (Velasco & Dobarganes, 2002).

Even though synthetic antioxidants like BHA, BHT & TBHQ are commonly used in food, toxicological effects have been reported in different species and these are banned in some countries. 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 extracts from plant species which are seen to possess antioxidant properties.

2.1.1. Rancidity Problem in vegetable oils

Vegetable oils are natural products of plant origin consisting of ester mixtures derived from glycerol with chains of fatty acid containing about 14 to 20 carbon atoms with different degrees of unsaturation. A highly saturated fatty acid level is confirmed to be of benefit in terms of storage ability when compared to more unsaturated vegetable oils. Auto-oxidation schemes are dependent on the hydrocarbon structure, heteroatom concentration, heteroatom speciation, oxygen concentration, and temperature (Ferrari *et al*., 2004).

Fats and oils are liable to rancidity even when they are not subjected to the intense conditions of industrial applications, (Eastman Chemical Company, 2001; Morteza- Semnani *et al*., 2006).

Pentane formation during initial stages of autoxidation is an indicative of rancidity in aged vegetable oils (Warner, 2002). Compared to polyunsaturated fatty acids, oleic acid is more stable towards oxidation both at ambient storage temperatures and at the high temperatures that prevail during the cooking and frying of food. Therefore, common edible oils with high amounts of oleic acid are slower to develop oxidative rancidity during storage or undergo oxidative decomposition during frying than those oils that contain high amounts of polyunsaturated fatty acids.

Modified oils containing high-oleic acid, low-linoleic and low-linolenic acids are produced by various methods including genetic modification and have been shown to be more stable to deterioration during deep-frying than regular oils. Unrefined oils prove to have a better stability than refined oils due to the fact that refining steps, in particular deodorization, remove a percentage of the tocopherol, which act as natural anti-oxidant in vegetable oils (Gertz *et al*., 2000). Natural antioxidants and pigments in oilseeds lead to extended shelf life and hence better oxidative stability (Oyedeji and Oderinde, 2006).

2.1.2. Rancidity in coconut oil

Hydrolytic, ketonic and oxidative rancidity occurs in coconut oil and oxidative rancidity produces the mild odour compared to other two. Development of ketonic rancidity in coconut oil is affected by temperature, water activity and sorbic acid (Kapila et al., 2005).

Compared to unrefined copra oil, rancidity problem was very less in virgin coconut oil and on consumption it reduced cholesterol, triglycerides, phospholipids, LDL and VLDL cholesterol levels and increased HDL cholesterol. 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).

Commercial coconut oil prepared by pressing copra and home made coconut oil prepared by boiling water extracts of scraped coconut kernel were analyzed 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 (Kapila *et al*., 2005).

Coconut oil extracted under hot conditions contained more phenolic substances than the coconut oil extracted under cold conditions (CECO). High temperatures used in the HECO favor the incorporation of more thermally stable phenolic antioxidants into coconut oil and hence consumption of HECO may result in improvement of antioxidant related health benefits (Kapila *et al.,* 2009).

Manalac and Harder (2001) analyzed the tocopherol content of coconut oil at different stages of refining. On an average, an initial tocopherol content of 721.06µg/g reduces to 38.9µg/g in the final product.

2.2. EFFECT OF ANTIOXIDANTS

Anti-oxidants are compounds which interrupt the oxidation process by preferentially reacting with the fat radical to form a stable radical which does not quickly react with oxygen (Eastman Chemical Company, 2007).

Antioxidants function either by inhibiting the formation of free alkyl radicals in the initiation step or by interrupting the propagation of the free radical chain. The most popular antioxidants are hydroxylphenol compounds with various ring substitutions. They are characterized by possessing low activation energies for the hydrogen donation process. The antioxidant radical is stabilized with its local electrons delocalized; hence antioxidant free radicals do not readily initiate other free radicals. They rather even react with lipid free radicals to form stable and complex compounds (Ohio State University, 2008).

Ruger *et al*. (2002) investigated the ability of various anti-oxidants and chelators like TBHQ, BHT, hydroquinone and ascorbyl palmitate at 0.01 and 1.28% to delay viscosity increase in soybean oil brought about by auto-oxidation. TBHQ was the most effective antioxidant among the different chemicals used.

Vegetable oils in their natural form possess constituents that function as natural antioxidants. Amongst them are ascorbic acids, tocopherol, carotene, chlorogenic acids and flavanols. Phenolic anti-oxidant Butylated Hydroxy toluene (BHT) was identified more effective than natural anti-oxidants in red pepper oil (Ullah *et al*., 2003).

Sesame oil is known to be significantly resistant to oxidative rancidity although it contains nearly 85% unsaturated fatty acids (Abou-Gharbia *et al*., 2000).

Free fatty Acid (FFA), peroxide value (POV)& lodine value (IV) of Khoa, a semi solid concentrated milk product were reduced by the addition of 200 ppm BHA &BHT (Rehman, 2003)

Synthetic antioxidants may be implicated in many health risks, including carcinogenesis(Khader, 1992). Therefore, the most powerful synthetic antioxidant (TBHQ) is not allowed for food application in Japan, Canada and Europe. Similarly, BHA has also been removed from the GRAS list of compounds. Several scientists have reported possibility of synthetic antioxidants having adverse health effects on humans exposed to them. Specifically, they are known to contribute to liver enlargement and an increase in microsomal activity (Khanahmadi and Janfeshan, 2006;Morteza-Semnani *et al*., 2006; Hemalatha & Ghafoorunissa, 2007; Yanishlieva & Marinova, 2001).

A large number of vegetables such as kale, spinach, Brussels sprout, broccoli, onion, eggplant, and cucumber are known to be rich sources of antioxidants (Hemalatha & Ghafoorunissa, 2007).

Phenols are one of the most important groups of natural antioxidants. They occur only in material of plant origin and are known to protect easily-oxidizable constituents of food from oxidation.

200ppm Ascorbyl palmitate preserved the tocopherol content in sunflower oil at 95^0C and delayed the onset of rancidity. Maduka *et al*. (2003) investigated the effectiveness of a Nigerian alcoholic beverage additive *Sacoglottis gabonensis* stem bark extract as an antioxidant for common stored vegetable oils. Inhibition of lipid peroxidation was found to be comparable to inhibitions obtained with treatment with vitamins C and E.

Tocopherol is an antioxidant that occurs naturally in vegetable oils that extends the initiation period of autoxidation and deterioration of fried oils (Ferrari et al., 2004).

Spices are known for their antioxidative properties. Vitamin C, β-carotene, tocopherol, capsaicin and some spice extracts are identified as potential antioxidants. Capsaicin retarded lipid oxidation of soybean oil during deep frying at 200°C however, it is not effective at 100°C (Sahin and Sumnu, 2009)

Essential oil and extract of *Ferulago angulata* ,a plant indigenous to the west of Iran, show preservative properties on vegetable oils at a minimum concentration of 0.02%. It was found more effective than TBHQ at concentrations of 0.5% (Khanahmadi and Janfeshan, 2006).

Trolox C, a water soluble derivative of vitamin E possessed greater antioxidant activity compared to Vitamin C in mechanically deboned turkey meat. Grape seed extract retarded oxidative rancidity in cooked turkey breast meat (Mellema,2003).

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).

Oleoresin of curry leaves obtained 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, namely 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).

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 acidation can be further prevented by adding capsaicin or tocopherol as antioxidant.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. CHIPS PREPARATION

Frying is one of the oldest methods of food preparation. It entails the application of heat from frying oil to achieve cooking and drying as well as flavour, crust, and color development in fried foods(Indira *et al*.,1999). A number of pretreatments namely coating, pre-drying, microwave precooking and osmo-dehydration, have been applied to improve the quality of fried product (Garcia *et al*., 2004; Rimac- Brncic *et al*., 2004; Adeniji and Tenkouano,2008).

The application of heat to food through immersion in hot oil causes several physical and chemical changes in both the frying oil and the food, resulting in changes that define the quality of the fried product (Dobarganes *et al*.,2000). Air-drying of plantain chips has been reported to yield significant differences in oil uptake and eating quality

During frying, moisture migrates from the interior of food to its surface as a combination of vapor and water due to pressure and concentration gradients generated by heating, creating a porous system within the food (Krokida *et al*.,2001; Sahin and Sumnu, 2009).

Oil quality changes as it is used repeatedly, due to chemical changes such as hydrolysis, polymerization, and oxidation, leading to the formation of free fatty acids (FFA), volatiles, acylglycerols, and acrylamides (Eastman chemical company,2001). Hydrolysis occurs when moisture released into the frying oil reacts with triglycerides to form FFA. Oxidation results from oil exposure to the atmosphere during frying at elevated temperatures. Multiple double-bond unsaturated fatty acids, such as linolenic acid, are more susceptible to oxidation than single-bond fatty acids like oleic acids.

Qualities of frying oil and fried foods are very closely related that is why adequate attention should be placed on the selection and condition of oil used in the frying operation. The higher the temperature, the higher the oil content of the chips during the initial frying period, when free water is still available in the product (Blumenthal,1991; Dunford, 2005).

Hydrocolloids are of special interest because they possess good barrier property against oxygen, carbon dioxide and lipids which could reduce oil absorption during deep-fat frying (Albert & Mittal, 2002; Rimac-Brncic *et al*., 2004). Some of the most useful hydrocolloids are cellulose derivatives such as methyl cellulose (MC), hydroxypropyl cellulose (HPC), hydroxypropyl methyl cellulose (HPMC) and carboxyl methyl cellulose (CMC). All these cellulose derivatives are water soluble with good film-forming properties (Priya, *et al*.,1996). Alginate and pectin are widely used in food systems to stabilize and to modify the rheology of food. The most useful property is gelation, which is formed by intermolecular association with polyvalent cations (Albert and Mittal, 2002; Rimac-Brncic *et al*., 2004). These results indicated that the interaction of $CaCl_2$ and hydrocolloids formed thermal gelation or cross-linked network to help cement the cell wall and enclose the outer surface of the tissue, consequently preventing oil penetration into the banana tissue during frying process (Mellema, 2003). The basic physical effect of deep-fat frying is water replacement by oil (Fellows, 2000)

The chemical changes in frying oil also result in changes in the quality of fried food. The fatty acid composition of the frying oil is an important factor affecting fried food flavor and its stability; therefore, it should be low level of polyunsaturated fatty acid such as linoleic or linolenic acids and high level of oleic acid with moderate amounts of saturated fatty acid (Morias, 2006). As a result, the quality of frying oil is important because of absorbed oil of fried products during deep frying.

2.4. EFFECT OF PACKING MATERIALS

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 upto 3 months while those in PFP, PP-Nyl-PP and MP were acceptable upto 4 months stored under ambient conditions(Roopa *et al.,* 2006).

Banana chips were packed in transparent and black polythene bags and stored in a 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. Rahman and Shams-Ud-

Din (2003) found that chips packed in low density polyethylene shortened the storage periods 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.

Materials and methods

3. MATERIALS AND METHODS

The present investigation on "Effect of antioxidants and packaging in controlling rancidity of banana chips during storage" was undertaken at the Department of Processing Technology, College of Agriculture, Vellayani, during the period 2009-2011.

The investigation was carried out as three different experiments.

1. Standardization of frying parameters for banana chips preparation.
2. Effect of antioxidants on quality of banana chips.
3. Storage stability and acceptability of antioxidant treated banana chips.

3.1. STANDARDIZATION OF FRYING PARAMETERS FOR BANANA CHIPS PREPARATION

3.1.1. Preliminary Preparation

Fully mature unripe banana bunches of cultivar Nendran were harvested between 85-95 days after inflorescence emergence from farmers' field at Kalliyoor, Thiruvananthapuram. 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.).

Chips were prepared using unrefined coconut oil by varying different parameters like temperature of frying medium, medium-material ratio, salt and turmeric concentration as detailed below

3.1.1.a. ***Temperature of the frying medium***

The temperature of the frying medium was fixed at three levels on the basis of smoke point of coconut oil.

H_1 - 160^0C
H_2 - 165^0C
H_3 - 170^0C

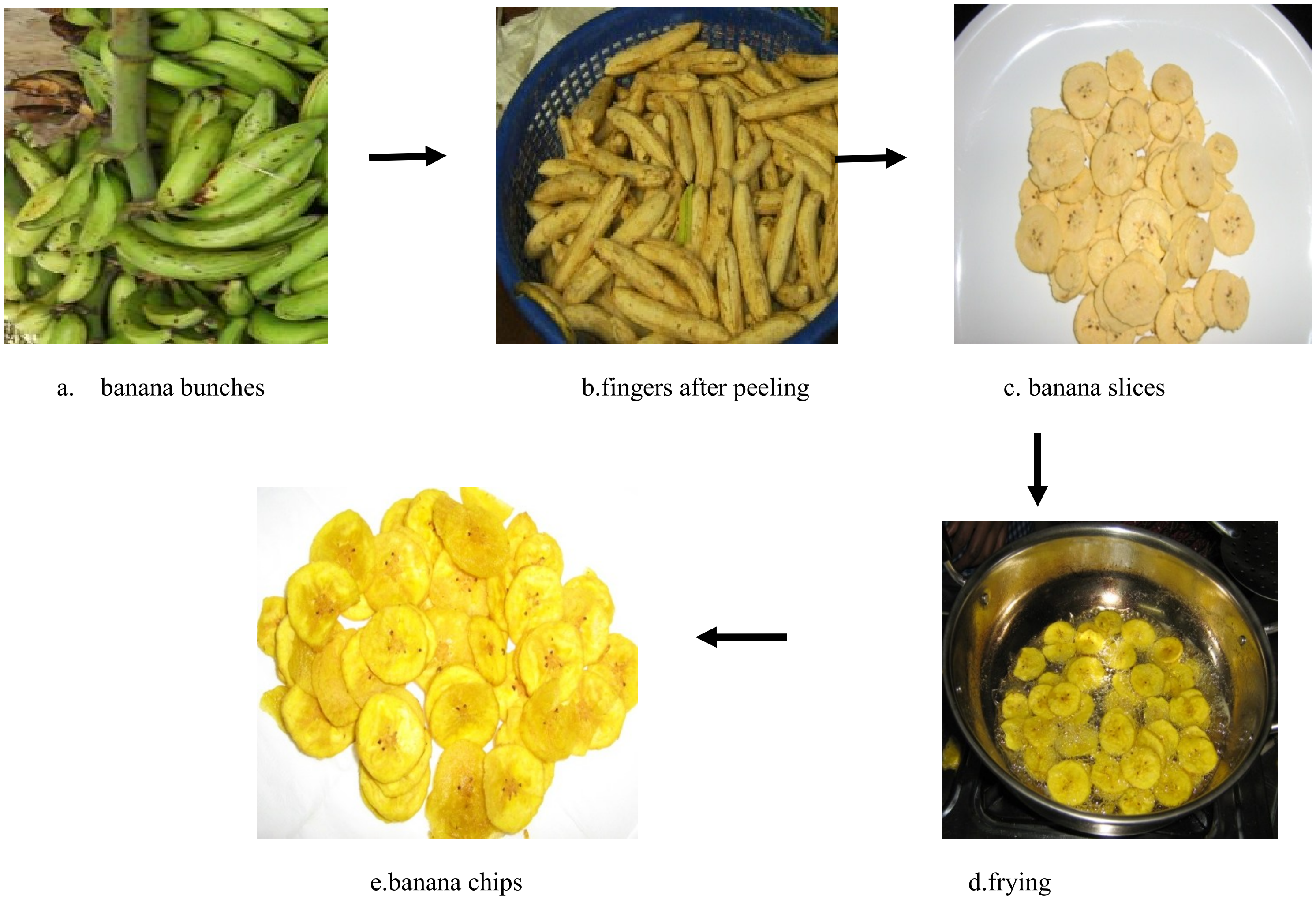


Plate 1. Flow chart for preparation of banana chips

3.1.1. b. *Medium-material Ratio*

The ratio of coconut oil to banana slices was considered on w/w basis at three levels.

M_1 – 2:1
M_2 – 3:1
M_3 – 4:1

3.1.1. c. *Salt concentration*

Three levels of salt concentration were tried

S_1 - 0.5%
S_2 - 0.6%
S_3 - 0.7%

3.1.1. d. *Turmeric concentration*

Two levels of turmeric concentration were tried

T_1 – 0.1%
T_2 – 0.15%

Salt and turmeric were applied together as 20% aqueous solution towards the end of frying.

There were a total of 54 combinations as detailed below, varying in temperature, medium-material ratio, salt and turmeric concentration with two replications forming a total of 108 chips samples.

The prepared banana chips were packed in Low Density Poly Ethylene (LDPE) covers and subjected to organoleptic analysis for standardization.

Fifty four treatment combinations, varying in temperature, medium-material ratio, salt and turmeric concentration

$H_1M_1S_1T_1$	$H_1M_2S_1T_1$	$H_1M_3S_1T_1$
$H_1M_1S_1T_2$	$H_1M_2S_1T_2$	$H_1M_3S_1T_2$
$H_1M_1S_2T_1$	$H_1M_2S_2T_1$	$H_1M_3S_2T_1$
$H_1M_1S_2T_2$	$H_1M_2S_2T_2$	$H_1M_3S_2T_2$
$H_1M_1S_3T_1$	$H_1M_2S_3T_1$	$H_1M_3S_3T_1$
$H_1M_1S_3T_2$	$H_1M_2S_3T_2$	$H_1M_3S_3T_2$
$H_2M_1S_1T_1$	$H_2M_2S_1T_1$	$H_2M_3S_1T_1$
$H_2M_1S_1T_2$	$H_2M_2S_1T_2$	$H_2M_3S_1T_2$
$H_2M_1S_2T_1$	$H_2M_2S_2T_1$	$H_2M_3S_2T_1$
$H_2M_1S_2T_2$	$H_2M_2S_2T_2$	$H_2M_3S_2T_2$
$H_2M_1S_3T_1$	$H_2M_2S_3T_1$	$H_2M_3S_3T_1$
$H_2M_1S_3T_2$	$H_2M_2S_3T_2$	$H_2M_3S_3T_2$
$H_3M_1S_1T_1$	$H_3M_2S_1T_1$	$H_3M_3S_1T_1$
$H_3M_1S_1T_2$	$H_3M_2S_1T_2$	$H_3M_3S_1T_2$
$H_3M_1S_2T_1$	$H_3M_2S_2T_1$	$H_3M_3S_2T_1$
$H_3M_1S_2T_2$	$H_3M_2S_2T_2$	$H_3M_3S_2T_2$
$H_3M_1S_3T_1$	$H_3M_2S_3T_1$	$H_3M_3S_3T_1$
$H_3M_1S_3T_2$	$H_3M_2S_3T_2$	$H_3M_3S_3T_2$

3.1.2. Organoleptic Evaluation

Organoleptic evaluation for judging consumer acceptability is essential for any food product (Bini, 2003). Sensory evaluation of the freshly prepared banana chips were done by a 10 member semi trained panel. They were asked to evaluate the appearance, colour, flavour, texture, taste and overall acceptability by a scoring rate using a nine-point hedonic scale (Appendix. I).

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

The scores given by the 10 judges were statistically analysed using Kendalls'(W) test and mean ranks were obtained for the quality parameters evaluated. The quality parameters were given comparative ranks from 1-5 based on the importance and weighted average ranks (W.A.R.) of the 54 combinations of chips were calculated using the formula,

$$W.A.R. = \frac{[(5\times \text{taste}) + (4\times \text{texture}) + (3\times \text{flavor}) + (2\times \text{colour}) + (1\times \text{appearance})]}{(5+4+3+2+1)}$$

Calculated weighted average ranks were compared with mean ranks for overall acceptability obtained from sensory scoring. Fourteen combinations of chips having higher values both for weighted average rank and overall acceptability were selected for further evaluation.

3.1.3. Evaluation of superior treatments from 3.1.1

Fourteen treatments which ranked top during organoleptic analysis (3.1.2.) were selected for repetition (Table 1.).

Banana chips were prepared using the selected fourteen treatments and were again analyzed for organoleptic parameters again as detailed in 3.1.2. The different parameters for the preparation of banana chips viz, temperature of frying medium, medium-material ratio, salt and turmeric concentration were standardized and used in the following experiments.

The selected parameters include

Temperature of frying medium - 165^0C

Medium -material ratio - 2:1

Salt concentration - 0.7%

Turmeric concentration - 0.15%

3.2. EFFECT OF ANTIOXIDANTS ON QUALITY OF BANANA CHIPS

Three different antioxidants were incorporated in banana chips viz., sodium ascorbate, tocopherol acetate and curry leaf powder. The most effective method of application of curry leaf to prevent rancidity of coconut oil was found out by conducting a preliminary evaluation in the laboratory.

3.2.1. Standardization of method of application of curry leaf as an antioxidant

The most effective method of application of curry leaf to prevent rancidity of coconut oil was found out. Curry leaf was added at the rate of 0.01% on w/w basis to unrefined coconut oil at smoke point of 165^0C in four different methods. Fresh curry leaves were dried in hot air oven at 60^0C for 6 hours and used for treatments from C_2 to C_4,

C_1 - Direct application of fresh curry leaves.

C_2 - Direct application of oven dried curry leaves.

C_3 - Dipping muslin cloth bag containing dried, ground curry leaves.

Table 1. Treatments selected for repetition after preliminary preparation

Sl.no	Treatment combination	Temperature of frying oil	Oil-slice ratio	Salt concentration (%)	Turmeric concentration (%)
1	$H_3M_2S_3T_1$	170	3:1	0.70	0.10
2	$H_1M_3S_1T_2$	160	4:1	0.50	0.15
3	$H_2M_2S_2T_1$	165	3:1	0.60	0.10
4	$H_1M_2S_1T_1$	160	3:1	0.50	0.10
5	$H_1M_3S_1T_1$	160	4:1	0.50	0.10
6	$H_3M_3S_1T_2$	170	4:1	0.50	0.15
7	$H_3M_2S_2T_1$	170	3:1	0.60	0.10
8	$H_2M_2S_1T_2$	165	3:1	0.50	0.15
9	$H_1M_2S_3T_2$	160	3:1	0.70	0.15
10	$H_2M_3S_3T_2$	165	4:1	0.70	0.15
11	$H_2M_1S_3T_1$	165	2:1	0.70	0.10
12	$H_2M_1S_2T_2$	165	2:1	0.60	0.15
13	$H_2M_1S_3T_2$	165	2:1	0.70	0.15
14	$H_1M_2S_2T_2$	160	3:1	0.60	0.15

H_1 -160 ^oC	M_1-2:1	S_1-0.5%	T_1-0.10%
H_2 -165 ^oC	M_2-3:1	S_2-0.6%	T_2-0.15%
H_3 -170 ^oC	M_3-4:1	S_3-0.7%	

C_4 - Direct application of dried, ground curry leaves.

C_5 - Control (without curry leaf application)

Treated unrefined coconut oil was stored in airtight glass bottles for one month. Peroxide value of different oil samples was recorded (Sadasivam & Manickam, 1992) after one month of storage to judge the level of rancidity in oil and the best method and form of curry leaf was selected for further experiments.

3.2.2. Preparation of banana chips with incorporation of antioxidants.

Banana chips were prepared using the technology standardized in 3.1 and three different antioxidants were incorporated in two different concentrations by two different methods.

Antioxidants -3

Sodium Ascorbate (S)
Tocopherol Acetate (T)
Curry leaf powder (C)

Concentrations – 2

0.01%

0.02%

Mode of application - 2

M_1- Presoaking treatment of banana slices

M_2 – Direct addition in frying oil

In presoaking treatment of banana slices, required quantity of antioxidants were dissolved in 100 ml water and the banana slices were soaked in it for 30 minutes. After 30 minutes, the slices were taken out, excess solution drained off and slices spread on muslin cloth for 30 minutes for surface drying before frying.

In direct addition, antioxidants were added directly to oil at 165^0C, before addition of the banana slices.

Salt and turmeric in 20% aqueous solution were added towards the end of frying.

Design - CRD

No: of treatments – 27 × 2 methods (54)

Replication -2

Antioxidants were applied in three different groups.

Group I – Application of each single antioxidant

Group II - Application of combination of two different antioxidants

Group III - Application of combination of three different antioxidants

All the groups of antioxidants were applied in both the methods along with control. Different antioxidant combinations tried in each method are shown below

GROUP I	S 0.01%
	S 0.02%
	T 0.01%
	T 0.02%
	C 0.01%
	C 0.02%
GROUP II	S 0.01%+ T 0.01%
	S 0.01%+ T 0.02%
	S 0.02%+ T 0.01%
	S 0.02%+ T 0.02%
	S 0.01 %+ C 0.01%
	S 0.01% + C 0.02%
	S 0.02 %+ C 0.01%
	S 0.02% + C 0.02%
	T 0.01 %+ C 0.01%
	T 0.01 %+ C 0.02%
	T 0.02% + C 0.01%
	T 0.02% + C 0.02%
GROUP III	S 0.01 % +T 0.01% +C0.01%
	S 0.01% +T 0.01% + C0.02%
	S 0.01% +T 0.02% + C0.01%
	S 0.01%+T 0.02% + C0.02%
	S 0.02 %+T 0.01% +C0.01%
	S 0.02% +T 0.01%+C0.02%
	S 0.02% +T 0.02 %+C0.01%
	S 0.02 %+T 0.02% +C0.02%
Control	S 0 +T 0 +C 0

S- Sodium ascorbate T- Tocopherol acetate C- curry leaf powder

The prepared banana chips samples were packed in LDPE covers and sensory evaluation was carried out using nine points hedonic scale by a 10 member semi trained panel as explained in 3.1. Based on sensory quality parameters, the top ranking 26 treatments were selected, 13 from each method, for further study.

The following observations were recorded to analyze the physical, chemical and sensory quality of antioxidant treated banana chips.

3.2.2.1. Physical qualities

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

3.2.2.1. a. *Yield*

Weight of fresh banana slices before frying and weight of chips after frying were recorded and yield was calculated as percentage

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

3.2.2. 1.b.*Moisture*

Moisture of ground chips was estimated using gravimetric method and expressed as percentage (Rangannna,1991).

3.2.2.1. 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 200 ml petroleum ether as solvent and expressed as percentage (AOAC, 1999).

3.2.2.1. 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 4.)

3.2.2.1.e.*Shrinkage ratio*

Ten banana slices from each treatment were taken and the surface area is plotted on a graph paper before and after frying, and the difference in diameter was calculated (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.

3.2.2.1. f. *Colour*

Colour of the antioxidant treated banana chips was recorded using spectrophotometer (Plate 3.) 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 colour indices were obtained.

L^* - luminance or lightness

a^* - greenness to redness

b^* - blueness to yellowness.

Yellowness index was computed using the formula

$$\text{Yellowness index} = \frac{142.86 \times (b)}{(L)}$$

Where, b = blueness to yellowness index at the time of observation

L = luminance or lightness index at the time of observation.

Plate 2. Food texture analyzer

Plate 3.Spectrophotometer assembly for colour measurement

3.2.2.1. g. *Textural quality*

Texture of the prepared banana chips was measured using a food texture analyzer (TAHD-Stable Microsystems, UK) (Plate 2.) 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, passes 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)

3.2.2.2. Chemical evaluation

Chemical parameters of banana chips viz., Peroxide value, Free fatty acid value and Iodine value, which represent the rancidity factors of deep fried products were recorded.

3.2.2. 2.a. *Free fatty acid value*

Free fatty acid value was determined by titrating the ground sample 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 sample (Sadasivam & Manikam, 1992).

3.2.2.2. b .*Peroxide value*

The amount of peroxide in the chips samples was determined by titration of powdered chips against 0.1 N thiosulphate in the presence of potassium iodide using

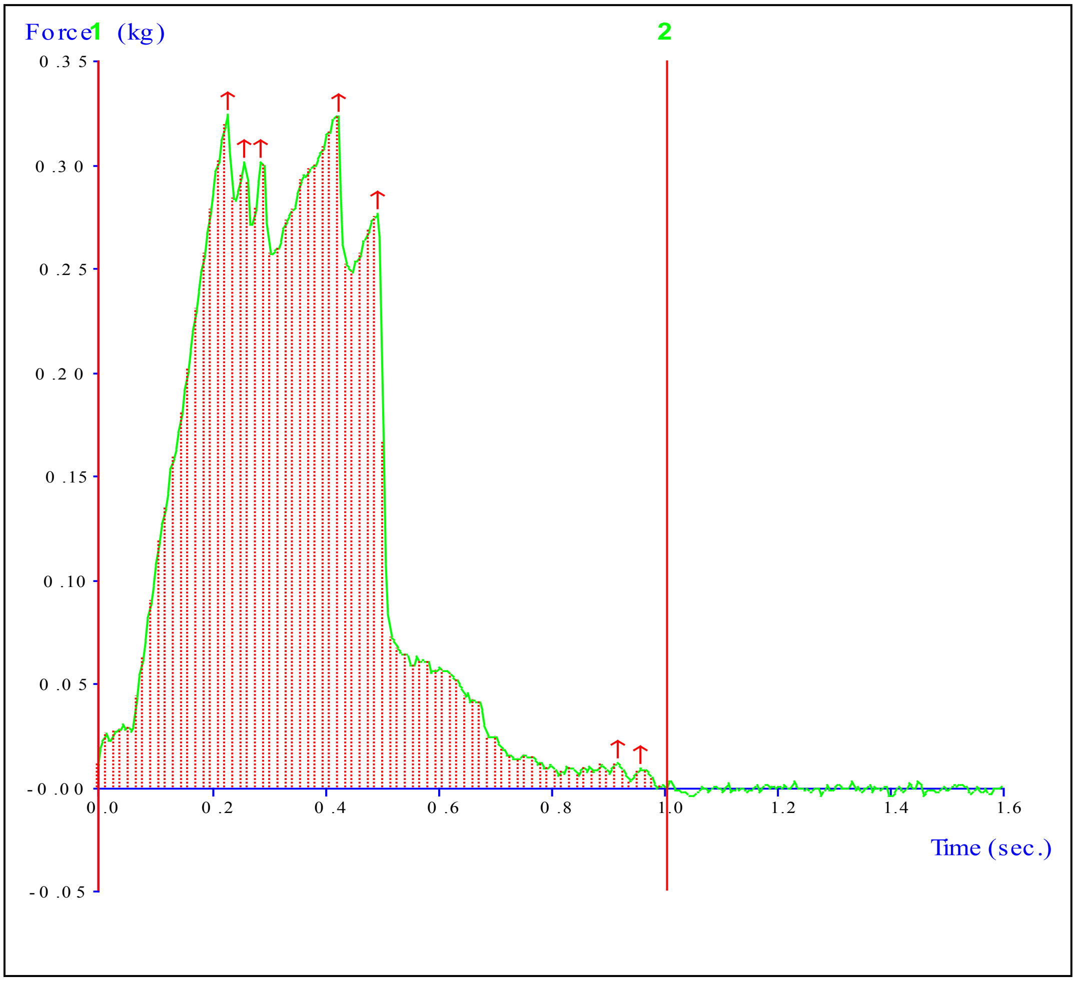


Fig. 1. Typical force-deformation curve of banana chips as measured by Food Texture Analyser

starch as indicator and expressed as milliequivalent peroxide/Kg sample (Sadasivam & Manikam,1992).

3.2.2.2.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 sample (Sadasivam & Manikam, 1992).

3.2.2.3. Sensory quality

Sensory quality of the antioxidant treated chips samples were organoleptically scored as described in 3.1.2.

3.3. STORAGE STABILITY AND ACCEPTABILITY OF ANTIOXIDANT TREATED CHIPS

Banana chips were prepared by the accepted 26 treatments, 13 from each method, from 3.2. along with control and the chips were packed in two different packaging materials such as

P_1 – laminated pouches with LDPE/ metalized polyester/LDPE

P_2 –LDPE pouches(plate 5.)

The following observations were recorded for the stored chips samples at regular intervals.

3.3.1. Physical qualities

Physical parameters of stored chips like moisture content, colour and texture were recorded at regular intervals.

Plate 4. Observation on integrity of chips

Plate 5. Packing materials used in the experiment

3.3.1. a. ***Moisture***

Moisture of chips was estimated at 15 days interval as described in 3.2.2.1.b.

3.3.1. b. ***Colour***

Colour of the stored banana chips was recorded monthly intervals for a period of three months as described in 3.2.2.1.f.

3.3.1. c. ***Textural quality***

Texture of the stored banana chips was recorded monthly intervals for a period of three months as described in 3.2.2.1.g.

3.3.2 Chemical qualities

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

3.3.2. a. ***Free fatty acid value***

Free fatty acid value of stored chips was determined at fortnightly intervals for a period of three months as detailed in 3.2.2.2.a.

3.3.2. b. ***Peroxide value***

The amount of peroxide in the stored chips samples was determined at fortnightly intervals for a period of three months as detailed in 3.2.2.2.b.

3.3.2.c. ***Iodine value***

Iodine value of stored chips was determined at fortnightly intervals for a period of three months as detailed in 3.2.2.2.c

3.3.3. Sensory quality

Sensory quality of treated chips samples were organoleptically scored at fortnightly intervals for a period of three months, as described in 3.1.2

3.4. COST OF PRODUCTION

Cost of production of 1 Kg of antioxidant treated chips was calculated as per the current market rate.

3.5. STATISTICAL ANALYSIS

The treatment combinations were grouped according to the method of application and combination of antioxidants and analyzed using one way ANOVA and significance was tested using CD and wherever necessary, t-test was performed. In organoleptic analysis, the different preferences as indicated by scores were evaluated by Kendalls' coefficient of concordance.

Results and Discussion

4. RESULT AND DISCUSSION

The experimental data collected from the investigation on "Effect of antioxidants and packaging in controlling rancidity of banana chips" were analyzed and the results presented and discussed in this chapter in three headings

4.1. Standardization of frying parameters for banana chips preparation.

4.2. Effect of antioxidants on quality of banana chips.

4.3. Storage stability and acceptability of antioxidant treated banana chips

4.1. STANDARDIZATION OF FRYING PARAMETERS FOR BANANA CHIPS PREPARATION.

4.1.1. Preliminary preparation

Chips were prepared from Nendran banana using unrefined coconut oil by varying different parameters like temperature of frying medium, medium-material ratio, salt and turmeric concentration. Appearance, colour, flavor, texture, taste and overall acceptability of the 54 treatment combinations of chips were evaluated organoleptically and mean ranks for different combinations are presented in Table 2.

4.1.1.a. *Appearance*

Banana slices treated with 0.7% salt and 0.1 % turmeric, when fried in 3:1 oil-slice ratio, at 170 ^{o} C ($H_3M_2S_3T_1$) produced chips with highest (38.00) mean rank for appearance.

The lowest mean rank (9.79) for appearance was obtained for chips produced from slices which received a combination of 0.6% salt and0.1% turmeric and fried in oil at 170 ^{o} C, in 2: 1 oil-slice ratio ($H_3M_1S_2T_1$). The improved appearance of chips may be due to more uniform cooking. Since the quantity of oil used for frying is more, slices got spread evenly avoiding the chances of sticking together and absorbing more oil which would have impaired the appearance.

Table 2: Mean ranks obtained in preliminary preparation for 54 chips combinations

Treatments	Mean ranks for quality parameters					
	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
$H_1M_1S_1T_1$	21.17	24.96	27.38	18.29	19.46	18.63
$H_1M_1S_2T_1$	11.54	13.25	27.00	36.50	34.58	24.75
$H_1M_1S_3T_1$	12.54	12.46	23.96	23.71	29.54	15.63
$H_2M_1S_1T_1$	32.42	33.29	27.21	35.13	32.46	38.17
$H_2M_1S_2T_1$	16.04	18.71	28.63	35.50	32.58	29.21
$H_2M_1S_3T_1$	19.38	20.25	35.38	35.54	39.25	31.54
$H_3M_1S_1T_1$	13.42	13.21	21.33	27.13	21.08	12.21
$H_3M_1S_2T_1$	9.79	7.79	31.42	33.67	40.21	23.71
$H_3M_1S_3T_1$	30.42	35.00	16.96	11.00	17.13	20.54
$H_1M_1S_1T_2$	35.13	31.38	30.71	27.33	24.13	35.79
$H_1M_1S_2T_2$	21.58	23.63	25.88	29.96	36.25	28.83
$H_1M_1S_3T_2$	13.71	17.50	26.79	24.13	27.33	19.21
$H_2M_1S_1T_2$	15.42	21.75	19.75	23.46	20.21	16.29
$H_2M_1S_2T_2$	17.63	20.08	26.96	40.00	40.79	27.46
$H_2M_1S_3T_2$	25.92	25.71	31.25	42.29	40.46	37.83
$H_3M_1S_1T_2$	30.83	30.04	28.63	38.42	34.67	36.50
$H_3M_1S_2T_2$	33.13	29.92	34.71	38.88	29.92	35.58
$H_3M_1S_3T_2$	33.25	31.42	34.25	33.58	30.38	34.75
$H_1M_2S_1T_1$	36.83	35.00	29.88	15.08	24.58	29.04
$H_1M_2S_2T_1$	29.08	33.29	28.29	9.38	16.42	18.50
$H_1M_2S_3T_1$	29.04	28.25	21.67	9.50	12.29	13.67
$H_2M_2S_1T_1$	29.58	26.96	23.63	19.46	17.67	19.96
$H_2M_2S_2T_1$	37.58	38.00	26.54	32.33	33.38	38.00
$H_2M_2S_3T_1$	34.50	27.42	31.58	33.83	34.83	34.67
$H_3M_2S_1T_1$	33.38	35.17	22.96	9.50	11.83	17.88
$H_3M_2S_2T_1$	34.58	37.63	29.92	20.00	22.83	27.75
$H_3M_2S_3T_1$	38.00	34.04	23.88	8.96	17.13	20.58
$H_1M_2S_1T_2$	21.83	19.04	26.08	31.42	33.88	25.83
$H_1M_2S_2T_2$	17.00	18.79	29.58	37.46	40.54	26.33
$H_1M_2S_3T_2$	24.71	24.83	34.83	35.54	39.08	32.96
$H_2M_2S_1T_2$	29.63	26.83	39.67	38.21	40.08	40.08
$H_2M_2S_2T_2$	36.29	34.38	29.75	23.38	29.00	32.00
$H_2M_2S_3T_2$	33.25	32.54	27.50	21.83	30.25	29.83
$H_3M_2S_1T_2$	36.17	34.21	17.04	22.29	14.33	22.46
$H_3M_2S_2T_2$	33.58	29.33	24.96	14.83	17.17	24.21

$H_3M_2S_3T_2$	18.21	23.42	30.08	40.63	39.21	35.21
$H_1M_3S_1T_1$	36.67	38.54	32.04	21.25	19.29	30.17
$H_1M_3S_2T_1$	26.79	26.13	16.54	21.96	11.38	14.96
$H_1M_3S_3T_1$	33.75	33.00	33.04	32.83	34.00	36.25
$H_2M_3S_1T_1$	33.83	30.50	22.75	35.75	25.33	29.88
$H_2M_3S_2T_1$	27.79	30.25	17.58	21.75	15.04	16.75
$H_2M_3S_3T_1$	18.04	19.17	29.04	30.13	34.88	27.92
$H_3M_3S_1T_1$	19.96	17.04	15.63	16.29	8.92	7.42
$H_3M_3S_2T_1$	22.13	21.79	28.13	25.54	26.29	20.38
$H_3M_3S_3T_1$	36.17	34.71	25.38	34.50	20.88	31.29
$H_1M_3S_1T_2$	37.75	37.50	37.25	40.63	41.21	46.71
$H_1M_3S_2T_2$	28.04	32.79	32.63	24.33	25.08	29.00
$H_1M_3S_3T_2$	34.00	28.29	28.38	27.71	31.54	31.75
$H_2M_3S_1T_2$	36.46	34.33	26.96	27.08	22.58	30.92
$H_2M_3S_2T_2$	23.67	25.88	24.54	13.21	17.67	19.54
$H_2M_3S_3T_2$	34.46	35.33	35.67	46.21	44.71	44.50
$H_3M_3S_1T_2$	36.46	40.54	32.96	28.21	29.54	38.46
$H_3M_3S_2T_2$	28.75	25.88	24.79	39.29	27.25	32.83
$H_3M_3S_3T_2$	23.75	23.88	25.71	20.21	24.50	20.71
Assym.sig	0.000	0.000	0.001	0.000	0.000	0.000

H_1 -160 ^{o} C	M_1-2:1	S_1-0.5%	T_1-0.1 %
H_2 -165 ^{o}C	M_2-3:1	S_2-0.6%	T_2-0.15%
H_3 -170 ^{o} C	M_3-4:1	S_3-0.7%	

This result is in conformity with Almedia and Noguira (1995), who reported that appearance is the first factor that determine the acceptance or rejection of a food product.

4.1.1.b. ***Colour***

The highest rank (40.54) for colour was obtained for chips produced from slices which received a combination of 0.5% salt and 0.15% turmeric and fried in oil at 170 ^{o} C, whose quantity was four times the quantity of slices ($H_3M_3S_1T_2$).The enhanced colour may be due to addition of more quantity of turmeric(0.15%).

The lowest rank (7.79) for colour was obtained for chips produced from slices which received a combination of 0.6% salt and 0.1% turmeric and fried in oil at 170 ^{o} C, whose quantity was twice the quantity of slices ($H_3M_1S_2T_1$).

4.1.1.c. ***Flavour***

The highest rank (39.67) for flavour was obtained for chips produced from slices which were treated with a combination of 0.5% salt and 0.15% turmeric and fried in 165 ^{o} C oil in 3:1 oil-slice ratio ($H_2M_2S_1T_2$).

The lowest rank (15.63) for flavour was obtained for chips produced from slices which received a combination of 0.5% salt and 0.1% turmeric and fried in oil at 170 ^{o} C, whose quantity was four times the quantity of slices ($H_3M_3S_1T_1$). The lowest rank for flavor for the slices fried in 4:1 slice-oil ratio may be due to the increased oil absorption. This is supported by the findings of Nema and Prasad (2004) who stated that when the quantity of frying oil is increased, oil absorption also increases.

4.1.1.d. ***Texture***

The highest rank (46.21) for texture was obtained for chips produced from slices which received a combination of 0.7% salt and 0.15% turmeric and fried in oil at 165 ^{o}C in 4: 1 oil : slice ratio ($H_2M_3S_3T_2$).

The lowest rank (8.96) for texture was obtained for chips produced from slices which received a combination of 0.7% salt and 0.1% turmeric and fried in oil at 170 ^{o} C, whose quantity was thrice the quantity of slices ($H_3M_2S_3T_1$). The poor texture for chips fried at a high temperature of 170 ^{o} C may be due to the rapid removal of moisture, making the chips more brittle.

4.1.1.e. ***Taste***

The highest rank (44.71) for taste was obtained for chips produced from slices which received a combination of 0.7% salt and 0.15% turmeric and fried in four times oil at 165 ^{o}C ($H_2M_3S_3T_2$).

The lowest rank (8.92) for taste was obtained for chips produced from slices treated with a combination of 0.5% salt and 0.1% turmeric and fried in oil at 170 ^{o}C, whose quantity was four times the quantity of slices ($H_3M_3S_1T_1$).

4.1.1.f. ***Overall acceptability***

The highest rank (46.71) for overall acceptability was obtained for chips produced from slices which received a combination of 0.5% salt and 0.15% turmeric and fried in four times oil at 160 ^{o}C ($H_1M_3S_1T_2$).

The lowest rank (7.42) for overall acceptability was obtained for chips produced from slices which received a combination of 0.5% salt and 0.1% turmeric and fried in four times oil at 170 ^{o}C ($H_3M_3S_1T_1$). Appearance and colour were poor for $H_3M_1S_2T_1$.But any treatments other than this did not record superior or inferior rank constantly. The treatments which recorded lowest ranks for all the parameters contained lower concentration of turmeric (0.10 %), which might have affected the acceptability of chips among the panelists. Lower ranks for sensory quality were noticed for higher and lower frying temperature. Higher temperature results in faster crust formation, resulting in higher oil uptake there by reducing acceptability. In lower temperature, retention time of chips in oil is increased, thereby increasing oil uptake. Chips with higher oil content will be having poor acceptability.

But none of the higher ranking treatments had other similar parameters. Hence, the weighted average ranks of the 54 chips combination were calculated based on the importance of characters. For any deep fried product, taste and texture are important, hence given highest ranks of 5 and 4 respectively. Flavour is an important character for banana chips, hence given a rank 3.Colour and appearance are given the ranks 2 and 1 respectively.

Chips combinations having higher calculated weighted average rank and mean ranks for overall acceptability were found out. The top ranking 14 treatments (Table 1.) were selected for further study.

4.1.2 Evaluation of superior treatments for confirmation

Fourteen superior treatments from preliminary trial (3.1.1.)were repeated and organoleptically scored as described in 3.1.2. The data on appearance, colour, flavor, texture, taste and overall acceptability of the 14 treatment combinations selected were statistically analyzed and mean ranks for each factors were calculated (Table 3).

Highest rank score for flavor (9.93), taste (9.41) and overall acceptability (9.76) were recorded by $H_2M_1S_3T_2$. This combination also showed second best rank for appearance (9.71) and texture (9.88). Higher or lower temperature affect chips quality adversely .Higher oil –slice ratio resulted in lower ranks for all parameters.

Table 3: Mean ranks for the superior treatments selected from preliminary trial.

Treatments	Mean ranks					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
$H_3M_2S_3T_1$	10.09	8.85	7.91	8.09	9.21	9.76
$H_1M_3S_1T_2$	7.85	8.65	9.21	8.65	8.76	9.47
$H_2M_2S_2T_1$	8.62	7.44	8.38	9.91	8.82	9.06
$H_1M_2S_1T_1$	7.94	8.68	9.15	8.12	8.85	8.94
$H_1M_3S_1T_1$	8.35	7.97	9.44	7.00	7.79	8.29
$H_3M_3S_1T_2$	4.82	5.62	4.59	5.32	5.56	4.76
$H_3M_2S_2T_1$	7.71	7.82	6.71	7.29	7.00	6.68
$H_2M_2S_1T_2$	8.53	8.91	7.06	7.41	7.62	8.15
$H_1M_2S_3T_2$	8.12	8.03	7.32	5.47	6.09	6.65
$H_2M_3S_3T_2$	6.18	6.03	6.85	6.91	4.76	4.21
$H_2M_1S_3T_1$	5.71	5.47	6.06	6.12	6.65	5.88
$H_2M_1S_2T_2$	7.88	7.09	7.09	8.29	8.15	7.62
$H_2M_1S_3T_2$	9.71	8.79	9.93	9.88	9.41	9.76
$H_1M_2S_2T_2$	5.50	5.74	8.29	8.53	8.32	7.76
Kendall,s W(a)	0.145	0.118	0.139	0.112	0.119	0.168
Assym.sig.	0.002	0.017	0.004	0.026	0.015	0.000

H_1 -160 ^{o} C M_1-2:1 S_1-0.5% T_1-0.10%

H_2 -165 ^{o} C M_2-3:1 S_2-0.6% T_2-0.15%

H_3 -170 ^{o} C M_3-4:1 S_3-0.7 %

The higher acceptability for banana chips fried in oil: slice ratio of 2:1 may be due to its reduced oil absorption. This is in accordance with the findings of Nema and Prasad (2004), who have stated that increased oil : slice ratio causes more oil absorption. Diaz *et al.,* (1996) also reported that a frying temperature of 165 ^{o} C produces banana chips with high quality. Based on the mean ranks of quality parameters, the most acceptable treatment was selected and different parameters for banana chips preparation were standardized as shown below.

Temperature of frying medium	- 165^{0}C
Medium -material ratio	- 2:1
Salt concentration	- 0.7%
Turmeric concentration	- 0.15%

4. 2. EFFECT OF ANTIOXIDANTS ON QUALITY OF BANANA CHIPS

4.2.1. Standardization of method of application of curry leaf as an anti oxidant

The most effective method and form of curry leaf to prevent rancidity of unrefined coconut oil were determined (Table 4.)

When the peroxide value of the treated oil samples were compared at the time of storage, lowest value (1.12 m.eq. O_2/kg) was recorded by direct addition of dried, ground curry leaves to oil which was on par with that of direct application of oven dried curry leaves (1.15 m.eq. O_2/ kg).

Oil sample in which dried, ground curry leaves was applied directly recorded the lowest peroxide value (3.14 m.eq. O_2/kg) after one month of storage also, which was significantly lower than the other treatments. The untreated sample recorded significantly higher values of 2.03 m.eq. O_2/kg and 5.18 m.eq. O_2/kg during periods of observation. Hence application of dried and ground curry leaves to unrefined coconut oil was identified as the best method and form of curry leaf application to

Table 4. Peroxide value of different method of application of curry leaf.

Treatments	Peroxide value (meq O_2/Kg)	
	At the time of addition	After 1 month of storage
Direct application of fresh curry leaves	1.18	4.22
Direct application of oven dried curry leaves	1.15	3.58
Dipping muslin cloth bag containing dried, ground curry leaves	1.23	3.29
Direct application of dried, ground curry leaves.	1.12	3.14
Untreated chips	2.03	5.18
CD(P=0.05)	0.04	0.06

prevent rancidity and this method was selected for the following experiments. The increased effectiveness of dried, ground curry leaf may be due to concentration of the antioxidant principles by drying; and its effective dispersion in the frying oil.

4.2.2. Preparation of banana chips with incorporation of antioxidants.

Banana chips were prepared by incorporating three different antioxidants in two different methods viz., presoaking slices in anti oxidants and direct addition of antioxidants in oil. From the 54 treatments, the top ranking 26 treatments were selected organoleptically, 13 from each method. Results of organoleptic analysis of 54 treatments including that of selected 26 numbers are shown in Table 5. The top ranking 26 treatments (Table 5.) were repeated along with control for further experiment.

4.2.2.1 Effect of antioxidants on physical quality of banana chips

Banana chips produced after treatment with anti oxidants, whether added directly in oil or slices presoaked in it, showed significant differences in yield, oil uptake (%) moisture content (%), shrinkage and integrity.

A. Pre soaking of slices in antioxidants

When banana slices soaked in antioxidants were made into chips, they showed significant variation in yield, oil uptake (%) moisture content (%), shrinkage and integrity (Table 6.) .

A.a. *Yield*

Antioxidants with in group I were inferior to untreated one in yield recovery. However 0.02% tocopherol acetate recorded the highest (68.6%) yield recovery next to untreated one and 0.01% sodium ascorbate the least (67.65).

Table 5. Mean sensory scores for the 54 antioxidant treated chips

Treatments	Mean ranks					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Presoaking slices in antioxidants						
S 0.01	**1.85**	**1.83**	**1.70**	**1.74**	**1.72**	**1.93**
S 0.02	1.15	1.17	1.30	1.26	1.28	1.07
T 0.01	1.52	1.48	1.71	1.63	1.65	1.65
T 0.02	**1.48**	**1.52**	**1.29**	**1.37**	**1.35**	**1.35**
C 0.01	1.50	1.46	1.35	1.35	1.33	1.25
C 0.02	**1.50**	**1.54**	**1.65**	**1.65**	**1.65**	**1.75**
S 0.01+C 0.01	2.50	2.50	2.46	2.56	2.52	2.42
S 0.01+C 0.02	2.52	2.52	2.52	2.46	2.42	2.52
S 0.02+C 0.01	**2.44**	**2.38**	**2.12**	**1.90**	**1.96**	**2.08**
S 0.02+C 0.02	**2.54**	**2.60**	**2.90**	**3.08**	**3.10**	**2.88**
T 0.01+C 0.01	2.90	3.06	2.35	1.40	1.79	2.19
T 0.01+C 0.02	2.33	2.15	2.73	3.17	3.25	2.90
T 0.02+C 0.01	**2.62**	**2.54**	**2.69**	**3.19**	**3.08**	**2.90**
T 0.02+C 0.02	**2.15**	**2.25**	**2.23**	**2.23**	**1.88**	**2.00**
S 0.01+T 0.01	2.33	2.35	2.08	2.19	2.13	2.04
S 0.01+T 0.02	**2.33**	**2.40**	**2.81**	**2.88**	**3.06**	**2.71**
S 0.02+T 0.01	2.73	2.58	2.04	1.81	1.73	2.10
S 0.02+T 0.02	**2.62**	**2.67**	**3.08**	**3.12**	**3.08**	**3.15**
S 0.01+T 0.01+C 0.01	**4.90**	**5.08**	**3.83**	**3.27**	**3.63**	**3.71**
S 0.01+T 0.01+C 0.02	**4.08**	**3.98**	**4.13**	**4.63**	**4.33**	**4.00**
S 0.01+T 0.02+C 0.01	3.17	3.27	3.98	3.79	3.98	3.21
S 0.01+T 0.02+C 0.02	1.02	4.06	5.19	5.19	5.33	5.06
S 0.02+T 0.01+C 0.01	**5.17**	**5.83**	**4.85**	**5.02**	**5.10**	**5.67**
S 0.02+T 0.01+C 0.02	5.60	5.52	5.15	5.08	4.96	5.56
S 0.02+T 0.02+C 0.01	**4.02**	**3.88**	**3.79**	**3.27**	**3.08**	**3.37**
S 0.02+T 0.02+C 0.02	4.50	4.38	5.08	5.75	5.60	5.42
Direct application of antioxidants in oil						
S 0.01	**1.57**	**1.60**	**1.60**	**1.54**	**1.54**	**1.58**

S 0.02	1.43	1.40	1.40	1.46	1.46	1.42
T 0.01	**1.62**	**1.56**	**1.46**	**1.40**	**1.35**	**1.35**
T 0.02	1.38	1.44	1.54	1.60	1.65	1.65
C 0.01	1.31	1.35	1.33	1.35	1.38	1.25
C 0.02	**1.69**	**1.65**	**1.67**	**1.65**	**1.62**	**1.75**
S 0.01+C 0.01	**2.77**	**2.71**	**2.02**	**1.46**	**1.75**	**1.88**
S 0.01+C 0.02	1.98	1.92	2.35	2.96	2.79	2.46
S 0.02+C 0.01	2.48	2.37	2.77	2.73	2.83	2.67
S 0.02+C 0.02	**2.77**	**3.00**	**2.87**	**2.85**	**2.63**	**2.98**
T 0.01+C 0.01	2.04	2.00	2.15	1.90	1.79	1.90
T 0.01+C 0.02	**2.96**	**2.60**	**2.00**	**1.73**	**1.77**	**1.98**
T 0.02+C 0.01	**2.56**	**2.75**	**3.02**	**2.92**	**3.06**	**3.06**
T 0.02+C 0.02	2.44	2.63	2.83	3.44	3.38	3.06
S 0.01+T 0.01	2.08	1.96	2.13	2.23	1.98	1.90
S 0.01+T 0.02	**2.13**	**2.08**	**2.44**	**3.21**	**2.83**	**2.56**
S 0.02+T 0.01	2.79	2.65	2.54	2.08	2.31	2.17
S 0.02+T 0.02	**3.00**	**3.31**	**2.88**	**2.48**	**2.88**	**3.37**
S 0.01+T 0.01+C 0.01	5.67	5.56	6.08	6.37	6.90	7.00
S 0.01+T 0.01+C 0.02	4.88	4.40	5.06	5.71	5.92	5.67
S 0.01+T 0.02+C 0.01	4.79	4.75	3.50	4.12	3.69	4.40
S 0.01+T 0.02+C 0.02	**4.44**	**4.33**	**3.69**	**3.27**	**3.77**	**3.29**
S 0.02+T 0.01+C 0.01	**3.92**	**4.13**	**5.40**	**6.02**	**5.96**	**5.40**
S 0.02+T 0.01+C 0.02	**3.58**	**4.25**	**3.48**	**2.17**	**1.88**	**2.23**
S 0.02+T 0.02+C 0.01	4.13	4.56	4.56	5.19	4.67	4.88
S 0.02+T 0.02+C 0.02	**4.58**	**4.02**	**4.23**	**3.10**	**3.19**	**3.12**
Assym. Sig.	0.000	0.000	0.001	0.000	0.004	0.000
Kendall,s W(a)	0.000	0.013	0.110	0.032	0.009	0.112

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

(Treatments shown in bold letters are top ranking and hence selected for further experiments.)

When antioxidants in group II were compared, untreated chips and chips from slices soaked in 0.02% each of sodium ascorbate and tocopherol acetate recorded the highest (70.0%) yield followed by chips treated with 0.02% sodium ascorbate + 0.01% curry leaf powder (69.85%). Slices treated with 0.02% tocopherol acetate + 0.01% curry leaf powder had produced chips of lowest (66.28%) yield recovery, which was on par with slices treated with 0.02% each of sodium ascorbate and curry leaf powder(67.75)

When the effect of antioxidants in group III was analyzed, combination of 0.02% sodium ascorbate, 0.02% tocopherol acetate and 0.01% curry leaf powder recorded the highest (70.08%) yield recovery, which was on par with all the other combinations in that group. When the yields of different groups were compared over different antioxidants, no significant difference was noticed. However higher yield (70%) was recorded by untreated chips. Increased yield of untreated banana chips may due to its higher moisture content compared to treated chips. All the antioxidants, whether applied individually or in combination recorded lower yield percentage ..

A.**b.** ***Oil uptake (%)***

When the banana chips were made using slices which are presoaked in anti oxidants, they showed significant variation in oil uptake in group I and III. However, chips from untreated slices recorded the highest (40.34%) oil uptake compared to all other chips prepared from the presoaked slices (Table 6.).

Though there was no significant difference between antioxidants in group II, a combination of 0.02% each of sodium ascorbate and curry leaf powder recorded the highest (38.3%) oil uptake. Under group III, chips from slices treated with 0.02% sodium ascorbate + 0.01% tocoherol acetate + 0.01% curry leaf powder had highest (39.45%) oil content and this was on par with all other treatments in group III, except

Table 6. Physical quality parameters of chips prepared from presoaked slices

Groups	Treatments	Yield (%)	Oil uptake (%)	Moisture (%)	Shrinkage ratio(%)	Integrity (%)
Group I	S 0.01	67.65	33.75	0.52	20.75	79.75
	T 0.02	68.60	32.77	0.46	21.12	82.50
	C 0.02	68.30	36.00	0.57	21.00	82.60
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	68.18	34.17	0.52	20.96	81.62
	CD (P=0.05)	1.39	4.09	0.22	NS	3.00
Group II	S 0.02+C0.02	67.75	38.30	0.91	24.00	75.00
	S 0.02+C0.01	69.85	37.95	1.21	23.30	66.50
	T 0.02+C0.02	68.60	36.00	0.73	21.90	74.00
	T 0.02+C0.01	66.28	37.36	0.80	24.00	83.00
	S 0.02+T 0.02	70.00	36.00	0.92	21.50	83.40
	S 0.01+T 0.02	69.50	36.15	0.94	22.85	80.63
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	68.66	36.95	0.92	22.93	77.09
	CD(P=0.05)	2.02	NS	0.11	NS	2.73
Group III	S 0.01+T 0.01+ C 0.01	66.00	38.02	0.89	25.75	79.00
	S 0.01+T 0.01+ C 0.02	68.90	36.80	0.80	22.00	85.12
	S 0.02+T 0.01+ C 0.01	68.00	39.45	0.75	22.25	77.05
	S 0.02+T 0.02+ C 0.01	70.08	37.83	0.86	22.40	80.00
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	68.24	38.03	0.82	23.15	80.29
	CD(P=0.05)	NS	1.77	0.06	NS	NS
CD for groups		NS	3.70	0.25	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

0.01% sodium ascorbate + 0.01% tocoherol acetate + 0.02% curry leaf powder, which recorded the lowest oil content of 36.8%.

Antioxidants with in each group had similar oil content except in group III. Untreated chips and chips treated with group III antioxidants had similar and high high oil content and this may adversely affect the quality of chips. The group I had least oil uptake (34.17%) making it more stable and acceptable. Application of single antioxidant resulted in least oil uptake followed by combination of two and three antioxidants. In the untreated chips, amount of residual moisture present was high, which would have increased the oil uptake. The reduced oil uptake of presoaked chips was also reported by Morais (2006). The reduced oil uptake of the treated chips is due to the presoaking treatment of antioxidants. Ikoko and kuri (2007) stated that presoaking the slices in osmotic solutions will reduce the oil uptake and moisture content of banana chips compared to control.

A.c. ***Moisture content (%)***

When moisture content of banana chips prepared from presoaked slices with in group I was compared (Table 6.), there was significant difference between the antioxidants with in group. Untreated chips had 0.93 % moisture .Slices treated with 0.02% tocopherol acetate produced chips with least (0.46%) moisture and 0.02% curryleaf powder, the highest (0.57%) among the group I treated chips.

The antioxidants in group II were significantly different from each other regarding the moisture content. Banana chips produced after treating slices with 0.02% each of tocopherol acetate and curry leaf powder recorded lowest (0.73%) moisture content in group II, which was on par with slices treated with 0.02% tocopherol acetate and 0.01% curry leaf powder (0.80%). Chips produced after soaking the slices in 0.02% sodium ascorbate + 0.01% curry leaf powder had maximum (1.21%) moisture content.

Antioxidants in group III exhibited significant difference in, producing chips of different moisture content. When a combination of 0.01% each of sodium ascorbate, tocopherol acetate and curry leaf powder was applied to banana slices, the resulting chips had maximum (0.89%) moisture content, which was on par with slices treated with slices treated with 0.02% sodium ascorbate, 0.02% tocopherol acetate and 0.01% curry leaf powder (0.86%). Chips produced from slices treated with 0.02% sodium ascorbate + 0.01% tocopherol acetate + 0.01% curry leaf powder had least (0.75%) moisture content.

When groups were compared, group II and III were similar to untreated chips and group I was inferior in moisture content. The reduction in residual moisture content of the antioxidant treated chips may be due to the effect of antioxidants. The antioxidants which entered the slices through soaking might have influenced the osmotic relation within the cell thereby enhancing the release of more moisture to the frying oil. The chips prepared from the presoaked slices had lower residual moisture and less oil retention compared to the untreated chips. This result agrees with the findings of Morias (2006) who stated that presoaking improves the acceptability and texture of chips by reducing the oil uptake.

A**.d.** ***Shrinkage ratio***

When the effect of different antioxidants in group I,II and III on shrinkage ratio of banana chips was compared (Table6.), there was no significant difference among the treatments. However, the lowest value for shrinkage ratio was recorded by chips treated with 0.01 % sodium ascorbate (20.75%) in group I, 0.02 % each of sodium ascorbate and tocopherol acetate (21.20%) in group II and a combination of 0.01% sodium ascorbate and 0.01 % tocopherol acetate and 0.02 % curry leaf powder (22.00%) in group III.

When the efficiency of different groups was compared over antioxidants there was no significant difference between the groups for shrinkage ratio. However group III treatments and untreated chips recorded the highest (23.15) shrinkage ratio and group I treatments recorded the least (20.96) shrinkage ratio. A group having least moisture content should have least shrinkage ratio and hence Group I antioxidants, which had least moisture content in the experiment recorded least shrinkage ratio also. The effects of pretreatments were shown to be significant on the shrinkage of the samples (Akinbode *et al*., 2010).

A.e. *Integrity*

When the effect of different antioxidants in group I (Table6.), was compared the highest value for integrity was recorded by the untreated chips (83.00%) and it was on par with all the treatments in group I except those treated with 0.01%sodium ascorbate (79.75%).

In group II, the highest integrity (83.40) was recorded by the chips made from slices soaked in a combination of 0.02 % each of sodium ascorbate and tocopherol acetate, which was on par with 0.02 % tocopherol acetate and 0.01 % curry leaf powder (83%) and untreated chips (83.00%). The lowest integrity (66.50) was recorded by chips treated with a combination of 0.02 % sodium ascorbate and 0.01 % curry leaf powder which was significantly different from the rest of the treatments in the group.

Though there was no significant difference in group III , the highest integrity was recorded by chips prepared from slices soaked in a combination of 0.01 % sodium ascorbate, 0.01% tocopherol acetate and 0.02 % curry leaf powder (85.12%). The lowest (77.05) integrity was recorded by the chips made from slices which received a combination of 0.02 % of sodium ascorbate, 0.01% tocopherol acetate and 0.01 % curry leaf powder.

When different groups of antioxidants were compared, there was no significant difference between them for percentage integrity. Untreated chips showed highest integrity (83.00) and the group II treatments recorded the lowest (77.09) integrity.

When physical parameters are evaluated for chips prepared from slices soaked in antioxidants, yield and shrinkage ratio are similar for all the groups. Even then untreated chips recorded the highest yield (70.00%), compared to the other three groups. Integrity was also high (83.00%) for untreated chips. This increased yield may be due to high moisture content (0.93%) and oil uptake (40.34%) of untreated chips. As these two are the major factors affecting quality of banana chips adversely, this increased yield cannot be considered as an advantageous factor. Group I antioxidants had lowest yield, oil uptake and moisture content. Chips with lowest moisture and oil uptake are considered to be of good quality and hence presoaking slices in group I antioxidants can be recommended for producing chips of good quality and within group I, all antioxidants had similar effect.

A.f. ***Yellowness index (colour)***

The colour of banana chips is most acceptable when it is having an average range of yellowness index. If colour is much above or below the average value,the chips become unacceptable. The colour of untreated chips prepared using the most acceptable variables in the previous experiment (4.1) was considered as the average index value (120.40)

When the effect of different antioxidants in group I on the yellowness index of banana chips was compared (Table 7.), chips made from 0.02% curry leaf powder had similar colour (117.55) as that of chips made from untreated slices . The lowest colour (108.66) was produced by 0.01 % sodium ascorbate, which had a faded appearance.

Table 7. Effect of antioxidants on the colour and texture of chips from presoaked slices

Groups	Treatments	Colour	Texture		
		Yellowness index	Hardness (N)	Toughness (Ns)	Crispness
Group I	S 0.01	108.66	5.92	1.98	5.25
	T 0.02	113.24	5.97	2.05	4.78
	C 0.02	117.55	6.17	1.69	4.22
	Control	120.40	5.64	1.18	4.32
	Group Mean	112.47	6.01	1.91	4.75
	CD	3.75	NS	NS	NS
Group II	S 0.02+C0.02	122.19	5.85	2.88	5.92
	S 0.02+C0.01	118.35	7.80	1.97	4.17
	T 0.02+C0.02	117.43	8.31	2.49	4.90
	T 0.02+C0.01	96.76	8.45	2.07	6.02
	S 0.02+T 0.02	114.70	6.88	1.75	6.05
	S 0.01+T 0.02	117.81	7.60	1.64	5.75
	Control	120.40	5.64	1.18	4.32
	Group Mean	115.24	7.31	2.13	5.68
	CD	3.75	1.47	1.39	1.75
Group III	S 0.01+T 0.01+ C 0.01	127.81	5.25	2.26	5.06
	S 0.01+T 0.01+ C 0.02	114.94	7.97	1.75	6.20
	S 0.02+T 0.01+ C 0.01	113.27	7.78	1.64	5.69
	S 0.02+T 0.02+ C 0.01	108.41	8.98	2.73	5.69
	Control	120.40	5.64	1.18	4.32
	Group Mean	116.11	7.79	2.12	5.66
	CD	3.75	2.45	1.15	1.33
CD for groups		2.53	1.52	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

In group II, chips made from slices treated with 0.02 % each of sodium ascorbate and curry leaf powder recorded the highest yellowness index (122.19), which was on par with that of untreated chips (120.40). Colour of chips prepared from slices soaked in 0.02 % sodium ascorbate+0.01% curry leaf powder, 0.01 % sodium ascorbate+0.02% tocopherol acetate and 0.02 % each of Tococpherol acetate and curry leaf powder had similar colour (118.35, 117.81 and 117.43 respectively) as that of untreated chips.

In group III category, none of the treatments had colour similar to that of untreated chips.The highest value((127.81) for yellowness was recorded by chips made from slices treated with 0.01 % each of the three antioxidants. This was the highest among all the chips prepared from presoaked slices, which gave a very dark yellow colour to chips.

There was significant difference between treated and untreated chips regarding colour. Group I antioxidants produced chips of least colour(112.47) whereas group III was having higher yellowness index (116.11), giving dark shade.. The acceptable colour of banana chips is golden yellow. Dark yellow colour may occur due to more oil absorption and pale yellow colour may occur due to improper cooking.

A.g. *Textural quality*

Texture of chips measured as hardness, toughness and crispness are shown in Table 7.

When the effect of different antioxidants in group I on the hardness of banana chips was compared, there was no significant difference between the treatments.

When the effect of group II antioxidants on the hardness of banana chips was compared, untreated chips recorded the lowest value (5.64 N) which was on par with chips treated with 0.02% each of sodium ascorbate and curry leaf powder(5.85 N) and 0.02 % each of sodium ascorbate and tocopherol acetate(6.88 N) indicating that they are softer compared to others.

Regarding group III antioxidants, chips treated with 0.01 % each of the three antioxidants recorded the lowest value (5.25 N) which was on par with untreated chips (5.64 N). 0.02 % tocopherol acetate + 0.01 % curry leaf powder produced hardest chips (8.45 N) in group II and when this treatment is combined with 0.02 % sodium ascorbate, that resulted in chips with hardness (8.98 N) in group III. In the case of hardness, group III resulted in chips with more hardness.

Similar to hardness, toughness of banana chips prepared from slices presoaked in group I did not show any significant difference among themselves. Chips made from untreated slices recorded the lowest toughness (1.18 Ns) indicating its superiority. There was no significant difference between different groups for toughness of banana chips, though they were significantly higher than the untreated chips. In group II, untreated chips had least toughness and this was on par with all other treatments except that treated with 0.02 % each of sodium ascorbate and curry leaf powder(2.88 Ns).Except this all other treatments had lower toughness. Group III antioxidants were similar to untreated chips except that of 0.02 % sodium ascorbate + 0.02 % tocopherol acetate+0.01 % curry leaf powder, which showed a higher toughness (2.73 Ns). Untreated chips were having the least hardness indicating its superiority.

When the effect of different antioxidants on the crispness of banana chips was compared ,there was no significant difference between the treatments in the group I .In group II, soaking in 0.02 % sodium ascorbate +0.02 % tocopherol acetate resulted in chips with highest crispness (6.05), making it more crisp. In the third group, all treatments were superior to untreated one. Treated chips were more harder and tougher than untreated chips, but they were more crispy than untreated chips.

B. Direct application of antioxidants in oil

B.a. ***Yield***

Banana chips prepared after adding the antioxidants directly in frying oil showed significant differences in yield recovery per cent (Table 8.) Comparing the effect of different antioxidants with in each group, the antioxidants did not show any variation in yield recovery among themselves in the group I, where antioxidants were applied individually. But they were inferior to untreated chips. However 0.01 % tocopherol acetate recorded the highest recovery of 66.1% and curry leaf powder 0.02%, the lowest (64%). This was similar to chips prepared from slices soaked in the antioxidants. Reduced yield in treated chips is due to reduced oil uptake (Morias, 2006).

In group II, where two antioxidants were combined, untreated chips recorded the maximum yield which was on par with banana chips prepared after adding sodium ascorbate and curry leaf each at 0.01% in frying oil, (68.6%). Lowest yield recovery of 65.45% was recorded by adding sodium ascorbate and curry leaf powder each at 0.02% directly to frying oil.

In group III, all treated chips had a lower yield compared to untreated chips. A combination of 0.02% sodium ascorbate, 0.01% tocopherol acetate and 0.02% curry leaf powder, resulted in chips of highest (67.15%) yield recovery, in group III which was on par with all other antioxidant combinations in same group except the chips, which received a combination of 0.01% sodium ascorbate, 0.02% tocopherol acetate and 0.02% curry leaf powder (64.4%).

Table 8. Physical parameters of chips prepared after adding antioxidants in oil

Groups	Treatments	Parameters				
		Yield (%)	Oil uptake (%)	Moisture (%)	Shrinkage ratio(%)	Integrity (%)
Group I	S 0.01	66.00	31.60	0.22	21.00	84.00
	T 0.01	66.10	31.10	0.27	23.00	88.50
	C 0.02	64.00	30.25	0.27	23.00	94.50
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	65.37	30.98	0.25	22.33	89.00
	CD (P= 0.05)	2.30	3.13	3.18	NS	3.54
Group II	S 0.02+C0.02	65.45	33.50	0.49	21.33	84.00
	S 0.01+C0.01	68.60	33.40	0.53	22.45	83.00
	T 0.02+C0.01	65.60	33.30	0.55	22.00	85.50
	T 0.01+C0.02	67.15	33.36	0.64	23.60	93.00
	S 0.02+T 0.02	66.06	30.88	0.37	21.20	89.50
	S 0.01+T 0.02	66.05	32.85	0.83	23.90	85.10
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	62.48	32.88	0.57	22.41	86.88
	CD(P= 0.05)	1.84	2.30	0.11	2.66	4.70
Group III	S 0.02+T 0.02+ C 0.02	66.60	34.65	0.93	23.05	87.75
	S 0.02+T 0.01+ C 0.01	67.00	38.80	0.88	21.25	90.05
	S 0.02+T 0.01+ C 0.02	67.15	40.53	0.89	22.25	90.50
	S 0.01+T 0.02+ C 0.02	64.40	40.15	0.70	24.01	85.50
	Control	70.00	40.34	0.93	23.15	83.00
	Group Mean	66.29	38.53	0.85	22.64	88.45
	CD(P= 0.05)	1.93	3.37	0.09	NS	3.66
CD for groups		2.85	3.70	0.25	NS	NS

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

Treated chips were inferior to untreated chips. Increased yield in untreated chips may be due to increased oil uptake and increased moisture content. Group II antioxidants had least yield (62.48%) compared to group I and group III. This result is different from chips prepared from presoaked slices and the difference may be due to difference in the treatments selected under the two methods.

B. b. ***Oil uptake (%)***

When the antioxidants in group I are compared,(Table 8.) there was no significant difference between different antioxidants. But they were different from untreated chips. However 0.02% curry leaf powder, when applied directly in oil, resulted in chips of least (30.25%) oil content and 0.01% sodium ascorbate resulted in chips of highest (31.6%) oil content.

There was significant difference between antioxidants in group II, and they were inferior to untreated chips. However a treatment combination of sodium ascorbate and tocopherol acetate each with 0.02% produced chips with lowest (30.88%) oil content. Chips produced by adding sodium ascorbate and curry leaf powder each at 0.02% recorded the highest (33.5%). These two combinations of antioxidants had the highest and lowest oil uptake in the presoaking method also.

In group III, antioxidant combination of 0.02% sodium ascorbate, 0.01% tocopherol acetate and 0.02% curry leaf powder produced chips with maximum (40.53) oil content and a combination of sodium ascorbate, tocopherol acetate and curry leaf powder each with 0.02% produced chips with lowest (34.65%) oil uptake.

Group I had least (30.98%) oil uptake and untreated chips had the maximum (40.34%) oil uptake.

B.c. ***Moisture content***

When the effect of antioxidants in group I were compared, all of them produced chips with similar moisture content. However chips produced after adding 0.01% sodium ascorbate recorded lowest (0.22%) moisture content, which was on par with all the other treatments, such as 0.01% tocopherol acetate and0.02% curry leaf powder. Both of them produced chips with 0.27% moisture content.

In group II, 0.01% sodium ascorbate + 0.02% tocopherol acetate produced banana chips with highest (0.83%) moisture content. Banana chips produced after adding 0.02% each of sodium ascorbate and tocopherol acetate recorded the lowest (0.37%) moisture content.

In group III, chips produced after adding sodium ascoorbate + tocopherol acetate + curry leaf powder, each at 0.02% recorded the highest(0.93%) moisture content, which was same as that of untreated chips. Chips produced after adding 0.01% sodium ascorbate +0.02% tocopherol acetate+ 0.02% curry leaf powder, recorded the minimum moisture content of 0.70% (Table 8.).

When groups are compared, group I recorded the least moisture(0.25 %) content followed by group II, group III and untreated chips. Chips having reduced oil uptake would have reduced moisture content and vice versa. Untreated chips, which recorded highest moisture content (0.93%) in the present experiment, recorded highest oil uptake (94.34%) also. The moisture-loss profile during deep-fat frying follows a pattern typical of most high-temperature dehydration processes. There is a quick initial drying rate followed by a much reduced rate when most of the moisture in food has been removed. (Akinbode *et al.*, 2010)

B. d. ***Shrinkage ratio***

When the effect of antioxidants in group I, on shrinkage ratio of banana chips was compared (Table8.), there was no significant difference among the treatments. However, the lowest value for shrinkage ratio was recorded by chips treated with 0.01 % sodium ascorbate (21.00%)

In group II category the lowest shrinkage ratio (21.20) was recorded by chips produced after adding 0.02 % each of sodium ascorbate and tocopherol acetate.

In group III there was no significant difference among the treatments with respect to shrinkage ratio. However the lowest (21.25%) shrinkage ratio was recorded by chips treated with a combination of 0.02% sodium ascorbate+ 0.01 %tocopherol acetate+ 0.01 % curry leaf powder .

When the efficiency of different groups was compared, there was no significant difference between the groups for shrinkage ratio, however treated chips recorded lower shrinkage ratio compared to untreated one. 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 dimension when heat-induced evaporation/drying occurs (Krokida *et al*., 2000). Shrinkage starts as a surface occurrence, 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, and a product with minimal shrinkage.

B.e. ***Integrity***

When the effect of different antioxidants in group I, on the integrity of banana chips was compared (Table 8.), the lowest value for integrity was recorded by the untreated chips (83.00%),which was on par with those treated with 0.01%sodium ascorbate (84.00%).Highest integrity (94.5)was recorded by chips with 0.02 % curry leaf powder making it more acceptable.

In group II, lowest integrity (83.00) was recorded when a mixture of 0.01 % sodium ascorbate and 0.01 % curry leaf powder is added in oil and this was same as in chips made from untreated slices (83.00%). Chips with highest integrity (93.00) is observed when combination of 0.01 % tocopherol acetate and 0.02 % curry leaf powder is added.

In group III ,the lowest integrity was recorded by chips prepared from untreated slices (83%) which was on par with chips which received a combination of 0.01% sodium ascorbate+0.02% tocopherolacetate+0.02% curry leaf powder(85.50%). Chips produced after adding 0.02 % sodium ascorbate+0.01 % tocopherol acetate+0.02% curry leaf powder recorded the highest(90.50) integrity. Though there was no significant difference between groups, untreated chips recorded least integrity. When antioxidants are added to oil, integrity is increased. During frying, moisture migrates from the interior of food to its surface as a combination of vapor and water due to pressure and concentration gradients generated by heating, creating a porous system within the food (Sahin and Sumnu, 2009).

When physical parameters like yield, oil uptake, moisture, integrity are considered together, all the groups had similar yield and integrity. Chips with lowest oil uptake (30.98) and moisture (0.25) can be considered to have good quality. Group I antioxidants with those favourable characters can be considered as of good quality. Among group I antioxidants, 0.02% curry leaf powder with lowest oil uptake (30.25) and highest integrity (94.90) can be considered as the antioxidant with good physical parameters.

B.f. Yellowness index (Colour)

Colour of chips prepared by adding different antioxidants in oil are shown in Table 9.

Table 9. Colour and texture of chips prepared after adding antioxidants in oil

		Colour	Texture		
Groups	Treatments	Yellowness index	Hardness (N)	Toughness (Ns)	Crispness
Group I	S 0.01	110.89	6.56	1.95	5.75
	T 0.01	129.44	5.45	2.68	5.41
	C 0.02	109.63	8.99	2.88	6.32
	Control	120.40	5.64	1.18	4.32
	Group Mean	116.65	6.99	2.50	5.83
	CD	3.75	2.60	2.17	1.29
Group II	S 0.02+C0.02	108.98	6.73	1.97	6.79
	S 0.01+C0.01	114.48	6.97	2.49	4.88
	T 0.02+C0.01	110.79	6.50	1.71	4.57
	T 0.01+C0.02	125.32	6.95	2.19	4.78
	S 0.02+T 0.02	106.31	5.77	1.59	4.22
	S 0.01+T 0.02	116.13	5.25	2.21	5.92
	Control	120.40	5.64	1.18	4.32
	Group Mean	113.66	6.36	2.03	4.98
	CD	3.75	NS	0.86	1.83
Group III	S 0.02+T 0.02+ C 0.02	156.97	6.10	1.53	4.17
	S 0.02+T 0.01+ C 0.01	124.91	5.50	1.91	9.06
	S 0.02+T 0.01+ C 0.02	102.85	6.70	2.82	6.92
	S 0.01+T 0.02+ C 0.02	119.07	6.54	1.66	6.45
	Control	120.40	5.64	1.18	4.32
	Group Mean	125.97	6.21	1.98	5.61
	CD	3.75	NS	1.13	1.79
CD for groups		NS	NS	NS	NS

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

When the effect of group I antioxidants are considered, all of them differed significantly from the colour (yellowness index) of the untreated chips(120.40) which was considered as the standard value.

When the yellowness index of group II antioxidants were compared with the standard colour value, chips prepared after adding 0.01 % sodium ascorbate +0.02 % tocopherol acetate had comparatively similar colour (116.13) as that of untreated chips.

In group III,chips prepared after adding 0.01 % sodium ascorbate+0.02 % tocopherol acetate+0.02 % curry leaf powder in oil had an yellowness index (119.07) similar to standard value.Chips made after adding a combination of 0.02 % each of sodium ascorbate, tocopherol acetate and curry leaf powder recorded the highest value(156.97),which was dark yellow in colour. The lowest yellowness index was recorded by chips treated with a combination of 0.02 % of sodium ascorbate, 0.01 % tocopherol acetate and 0.02 % curry leaf powder (102.85), which gave a faded appearance.

There was no significant difference between different groups for yellowness index. The frying process leads to the formation of a crispy hard crust and golden brown coloration in chips due to high frying temperatures, significant moisture loss, and chemical changes including starch gelatinization, protein denaturation, caramelization, and Maillard reaction. The extent of color development is determined by the moisture content, water activity, frying oil quality, food composition, and heat intensity (Akinbode *et al*., 2010).

B.g. *Textural quality*

Texture of chips, as measured by hardness, toughness and crispness, prepared by adding different antioxidants in oil are shown in Table 9.

When the effect of different antioxidants in group I on the hardness of banana chips was compared, the least was recorded by chips prepared after adding 0.01 % tocopherol acetate (5.45 N) and 0.01% sodium ascorbate (6.56 N) in the first group. The combination of 0.01 % sodium ascorbate and 0.02 % tocopherol acetate recorded the lowest hardness (5.25 N) in the second group though there was no significant difference among the different treatments within the group. Antioxidants with in group III were similar in hardness of chips. However, a combination of 0.02 % sodium ascorbate, 0.01 % tocopherol acetate and 0.01 % curry leaf powder recorded the lowest hardness (5.50 N) in the third group.

When the efficiency of different groups was compared, Group III produced the minimum hardness (6.21 N) .

When the effect of different antioxidants on the toughness of banana chips was compared, chips made from 0.02 % curry leaf powder recorded the highest value (2.88 Ns). The lowest toughness was recorded by chips treated with 0.01 % sodium ascorbate (1.95 Ns) in the first group, though there was no significant difference among the other treated chips. The combination of 0.02 % each of sodium ascorbate and tocopherol acetate recorded the lowest toughness (1.59 Ns) in the second group and it was on par with all the other combinations except the combination of 0.01% each of sodium ascorbate and curry leaf (2.49 Ns). The combination of 0.02 % each of the three antioxidants recorded the lowest toughness (1.53 Ns) in the third group and it was on par with all other treatments in the group, except 0.02% sodium ascorbate + 0.01% tocopherol acetate + 0.02% curry leaf powder (2.82 Ns).

There was no significant difference between different groups for toughness of banana chips, though they were significantly lower than the untreated chips.

When the effect of different antioxidants on the crispness of banana chips was compared ,the least crispness was recorded by chips treated with 0.01 % tocopherol acetate (5.41) in the first group and it was on par with all other treatments in the group I. The combination of 0.02 % each of sodium ascorbate and tocopherol acetate recorded the lowest crispness (4.22) in the second group, and it was on par with all other treatments in the same group. Combination of 0.02 % each of the three antioxidants recorded the lowest crispness (4.17) in the third group and it was on par with 0.02% sodium ascorbate + 0.02% tocopherol acetate + 0.01% curry leaf powder.

Lower values for hardness and toughness are considered as good textural quality parameters for banana chips. It should have higher crispness value also. Treated chips, which recorded low hardness, toughness and high crispness value, can be considered as one with highly acceptable texture.

The antioxidants selected in the two methods of application were different. Hence it is difficult to compare the efficiency of two methods. But some antioxidants were common in both the methods. If the efficiency of any such common treatment is compared in two methods, efficiency of methods can be judged. While comparing the groups, group I antioxidants were better as they had lower moisture content and oil uptake. Hence the efficiency of two such common treatments from group I category viz., 0.01 % Sodium ascorbate and 0.02 % curry leaf powder was compared in both the methods (Fig 2.) regarding important physical quality parameters like moisture, oil uptake and integrity. It is seen that the chips prepared after adding antioxidants in the oil had less oil uptake (Fig 2.a), lower moisture content (Fig 2.b), and better integrity (Fig 2.c) compared to the chips prepared from presoaked slices. By presoaking banana slices in solution of antioxidants,

Fig 2. Efficiency of method of application in improving physical qualities

Fig. 2.a. Oil uptake

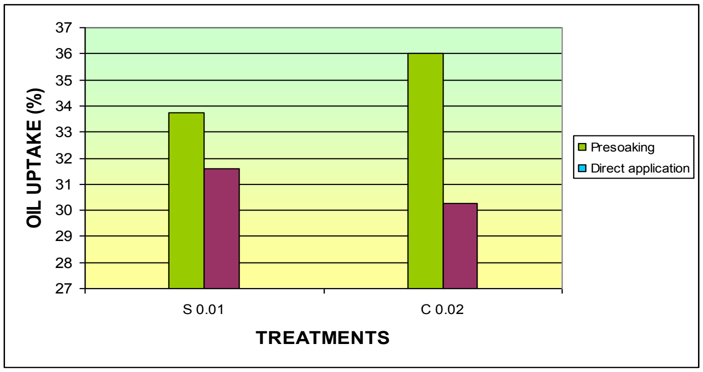


Fig.2.b. Moisture content

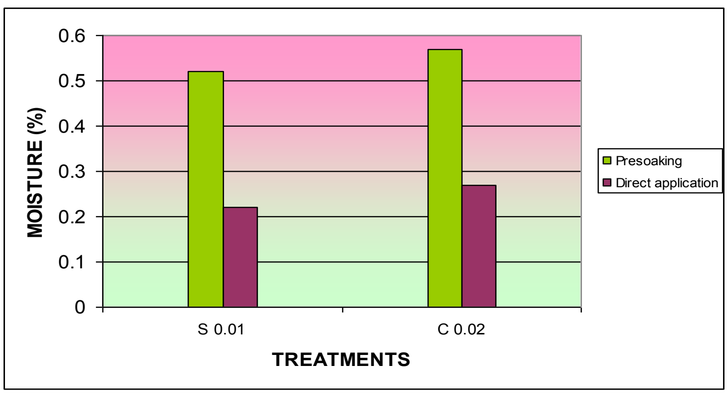
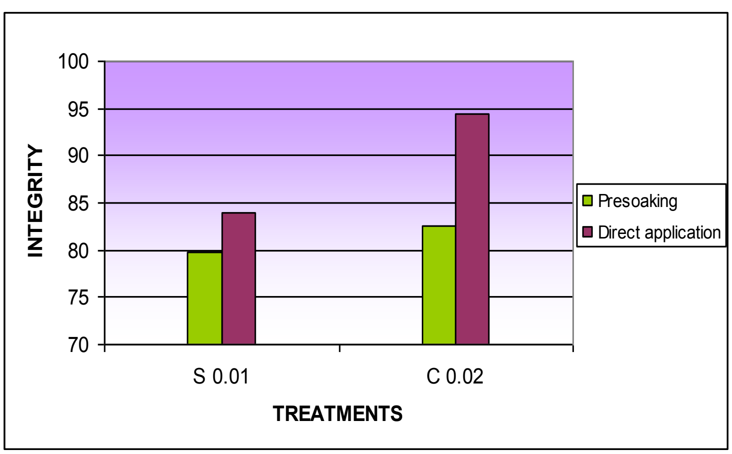


Fig. 2.c. Integrity



S-Sodium ascorbate C-Curry leaf powder

moisture content of slices is increased. As there is a positive correlation between moisture content and oil uptake, slices with a higher moisture content in the presoaking method get more chance for oil absorption. The vapor escape paths eventually become an access for fat intrusion into a frying product. The type and quality of frying oil, food composition, and pretreatment prior to frying determine to a great extent the amount of oil that is absorbed and, subsequently, the quality of the fried product(Adeniji,2005). But in direct application, as the slices are not exposed to any such condition before frying, the chance for getting additional moisture is prevented, there by reducing the oil uptake. The result is in accordance with the findings of Blumenthal (1991), who have stated the importance of moisture content and residence time of slices in oil. In presoaking method, the residence time is also more and hence affecting the oil uptake. Since oil content and residual moisture are two important factors which affect the shelf stability of chips, the direct application method can be considered superior to the presoaking method.

4.2.2.2. Effect of antioxidants on chemical quality of banana chips

A. Pre soaking of slices in antioxidants

A.a. ***Free fatty acid value (FFA value)***

When the effect of different group I antioxidants on free fatty acid value of banana chips was compared, chips made from slices treated with 0.01 % sodium ascorbate recorded the lowest value (1.45 mg KOH/g)(Table 10.). Untreated chips recorded the highest free fatty acid value (2.14 mg KOH/g). This is in accordance with the findings of Rehman (2003), who has reported a lower free fatty acid value in antioxidant treated potato chips compared to control (Table 10.).

In group II, slices soaked in 0.02% tocopherol acetate+0.01% curry leaf powder recorded the highest(2.15 mg KOH/g) FFA value which was on par with

Table 10. Chemical parameters of chips from presoaked slices

Groups	Treatments	Chemical parameters		
		Free Fatty Acid value	Peroxide value	Iodine Value
Group I	S 0.01	1.45	6.02	11.61
	T 0.02	1.80	7.13	11.69
	C 0.02	1.90	6.64	11.63
	Control	2.14	6.88	10.01
	Group Mean	1.72	6.93	11.22
	CD	0.09	NS	1.52
Group II	S 0.02+C0.02	2.00	4.85	11.85
	S 0.02+C0.01	1.90	6.70	11.68
	T 0.02+C0.02	2.02	6.54	11.72
	T 0.02+C0.01	2.15	5.92	12.03
	S 0.02+T 0.02	1.90	5.97	12.09
	S 0.01+T 0.02	1.85	6.17	11.97
	Control	2.14	6.88	10.01
	Group Mean	1.97	6.02	10.36
	CD	0.19	1.96	1.63
Group III	S 0.01+T 0.01+ C 0.01	1.90	5.85	12.14
	S 0.01+T 0.01+ C 0.02	1.82	6.80	10.74
	S 0.02+T 0.01+ C 0.01	2.08	8.31	10.79
	S 0.02+T 0.02+ C 0.01	1.88	8.45	10.63
	Control	2.14	6.88	11.01
	Group Mean	1.92	7.35	10.18
	CD	0.06	1.40	NS
CD for groups		0.31	NS	NS

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

that of untreated chips (2.14 mg KOH/g),chips with 0.02% each of tocopherol acetate and curry leaf powder and chips with 0.02 % each of sodium ascorbate and curry leaf powder(2.00 mg KOH/g). The lowest FFA value(1.85 mg KOH/g) was recorded by chips treated with 0.01% sodium ascorbate +0.02% tocopherol acetate .

Untreated chips was on par with that of chips with 0.02 % sodium ascorbate +0.01% tocopherol acetate +0.01% curry leaf powder(2.08 mg KOH/g).The lowest free fatty acid content(1.82 mg KOH/g) was recorded by 0.01%sodium ascorbate +0.01% tocopherol acetate +0.02% curry leaf powder ,which was on par with chips treated with 0.02% sodium ascorbate +0.02% tocopherol acetate +0.01% curry leaf powder(1.88 mg KOH/g).

Chips treated with group II and group III antioxidants had similar free fatty acid value (1.97 mg KOH/g and 1.92 mg KOH/g respectively) with untreated chips (2.14).Group I recorded the lowest value(1.72 mg KOH/g). Lower free fatty acid value of the treated chips is due to the presence of antioxidants in the banana slices through soaking. This is in accordance with the findings of Kapila *et al*., (2005), who have reported a lower free fatty acid value due to the presence of natural antioxidants.

A.b. *Peroxide value*

When the effect of different antioxidants in group I, on the peroxide value of banana chips was compared, there was no significant difference between treatments in the group I (Table 10.).

Among group II antioxidants, 0.02% sodium ascorbate +0.02 % curry leaf had a lower peroxide value(4.85 meq.O_2/Kg) than the untreated chips. Rehman (2003) also reported a lower peroxide value in antioxidant treated potato chips compared to control.

In group III,the peroxide value of banana chips treated with 0.01 % of each antioxidant recorded the lowest value(5.85 meq.O_2/Kg) which was on par with that of untreated chips (6.88 meq.O_2/Kg). The highest peroxide value(8.45 meq.O_2/Kg) was recorded by chips treated with 0.02%sodium ascorbate +0.02% tocopherol acetate +0.01% curry leaf powder which was on par with that of chips treated with 0.02%sodium ascorbate +0.01% tocopherol acetate +0.01% curry leaf powder(8.31 meq.O_2/Kg).

When different groups were compared, there was no significant difference between the groups for peroxide value. In general, oxidation reactions in oil produce free radicals which start off chain reactions. Antioxidants terminate these chain reactions by probably removing free radical intermediates, or by being oxidized themselves (Aluyor and Ori-Jesu,2008). The lower peroxide value of the treated chips is due to the action of the antioxidants in the oil. Kapila *et al*., (2005) observed a higher peroxide value due to the removal of natural antioxidants, thus supporting the results.

A**.c.** ***Iodine value***

Effect of different antioxidants in group I on the iodine value of banana chips was significantly different. (Table 10.). Banana chips made from slices treated with 0.02 % tocopherol acetate recorded the highest value (11.69) and untreated chips recorded the lowest value (10.01). Rehman (2003) also reported a higher iodine value in antioxidant treated potato chips compared to control.

In group II all the treatments had significantly higher values than the untreated chips(10.01)). The highest value was recorded by a combination of 0.02 % sodium ascorbate and 0.02 % tocopherol acetate (12.09)

In group III, all the treatments had iodine value on par with that of untreated chips. When different groups of antioxidants were compared, there was no significant difference between the groups for iodine value. This is supported by the findings of Kapila *et al*.,(2005), who has stated that iodine value is not changed due to incorporation of antioxidants.

When chemical parameters were considered together ,group I had lowest free fatty acid value (1.72) and highest (11.22) iodine value, hence having superior quality

B. Direct application of antioxidants in oil

When antioxidants were directly applied in frying oil, chips showed significant variation in free fatty acid value, peroxide value and iodine value (Table 11.)

B.a. ***Free fatty acid value***

When the effect of different group I antioxidants on the free fatty acid value of banana chips were evaluated, all the treatments in all the three groups had significantly lower values than the untreated chips (2.14 mg KOH/g). Antioxidants in group I were on par in producing chips of similar free fatty acid value.

In group II, the lowest value was recorded by chips treated with a combination of 0.02 % tocopherol acetate+0.01 % curry leaf powder(1.22 mg KOH/g),which was on par with that of 0.01 % each of sodium ascorbate and curry leaf powder(1.30 mg KOH/g).

The lowest (1.34 mg KOH/g) FFA value was recorded by a combination of 0.02 % sodium ascorbate +0.01 % tocopherol acetate+0.02 % curry leaf powder in group III. On comparing different groups, untreated chips had higher FFA value compared to treated chips. There was no significant difference between the three groups. However group I recorded the lowest value (1.35 mg KOH/g) .This is in accordance with findings of Rehman (2003) who reported a decreased FFA value in

Table 11. Chemical parameters of chips prepared after adding antioxidants in oil

Groups	Treatments	Chemical parameters		
		Free Fatty Acid value	Peroxide value	Iodine Value
Group I	S 0.01	1.38	5.31	11.49
	T 0.01	1.30	6.22	12.19
	C 0.02	1.37	3.88	12.52
	Control	2.14	6.88	10.01
	Group Mean	1.35	5.13	11.22
	CD	0.14	NS	1.22
Group II	S 0.02+C0.02	1.47	6.60	11.67
	S 0.01+C0.01	1.30	6.58	11.92
	T 0.02+C0.01	1.22	6.73	11.12
	T 0.01+C0.02	1.84	6.72	12.11
	S 0.02+T 0.02	1.45	5.51	11.95
	S 0.01+T 0.02	1.41	6.93	12.00
	Control	2.14	6.88	10.01
	Group Mean	1.45	6.51	11.25
	CD	0.13	1.23	1.55
Group III	S 0.02+T 0.02+ C 0.02	1.41	5.80	10.82
	S 0.02+T 0.01+ C 0.01	1.66	6.61	10.51
	S 0.02+T 0.01+ C 0.02	1.34	8.41	11.74
	S 0.01+T 0.02+ C 0.02	1.61	6.33	10.34
	Control	2.14	6.88	10.01
	Group Mean	1.50	6.79	10.85
	CD	0.06	1.52	NS
CD for groups		0.31	NS	NS

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

antioxidant treated chips. It is generally established that antioxidants function as oxygen interceptors in the oxidative process thereby breaking the chain reaction that perpetuates the process.

B.b. ***Peroxide value***

When the effect of different group I antioxidants on the peroxide value of banana chips was evaluated, there was no significant difference between treatments in the group (Table11). Chips made from slices treated with 0.02 % curry leaf powder recorded the lowest value (3.88 meq O_2 /Kg) and untreated chips recorded the highest value (6.88 meq O_2 /Kg).

In group II,antioxidant combination of 0.02 % sodium ascorbate +0.02 % tococpherol acetate recorded the lowest peroxide value (5.51 meq O_2 /Kg) than all other antioxidants.

In group III chips prepared after adding ,a combination of 0.02 % sodium ascorbate + 0.01 %tocopherol acetate+0.02% curry leaf powder recorded highest peroxide value(8.41 meq O_2 /Kg) .The lowest value (5.80 meq O_2 /Kg) was recorded by a combination of 0.02 % each of the three antioxidants.

When different groups were compared, there was no significant difference between groups for peroxide value, though they were lower than untreated chips. The lowest value (5.13 meq O_2 /Kg) was recorded by group I. In general terms, oxidative rancidity in oils occurs when heat, metals or other catalysts cause unsaturated oil molecules to convert to free radicals. These free radicals are easily oxidized to yield hydroperoxides and organic compounds, such as aldehydes, ketones, or acids which give rise to the undesirable odors and flavours, characteristic of rancid fats.

B.c. ***Iodine value***

When the effect of different antioxidants in group I and group II on the iodine value of banana chips was compared (Table11), all the treatments had significantly higher iodine value compared to chips made from untreated slices (10.01)

In group II, all antioxidants were superior to untreated slices, except combination of 0.02 % tocopherol acetate and 0.01 % curry leaf. In group III ,there was no significant difference between the treated and untreated chips for iodine value.

When different groups were compared, there was no significant difference between the groups for iodine value.

In general, when the chemical quality parameters are compared, the treated chips performed better than control as in the presoaking method. This result is supported by the findings of Noor and Augustin(1984); Rehman (2003);Kapila *et al*., (2005), who had stated that addition of antioxidants will result in a lower free fatty acid value, peroxide value and a higher iodine value than the control.

None of the treatments showed a superior performance in chemical quality when it is applied as a presoaking method. 0.01% sodium ascorbate was better compared to other treatments. But when, applied directly in oil, 0.02% curry leaf powder showed superior performance by recording lower free fatty acid value, peroxide value and a higher iodine value. Chips treated with 0.02% had highest integrity also. As in physical quality parameters efficiency of two methods was compared (Fig 3.) by judging the performance of common treatments(0.01 % sodium ascorbate and 0.02 % curry leaf powder) selected in both the methods. When the efficiency of two methods was compared, the chemical parameters like free fatty acid content(Fig 3.a) and peroxide value (Fig 3.b)were lower in direct application, indicating its efficiency .

Fig 3. Efficiency of method of application in improving chemical parameters

Fig 3a. Free fatty acid value

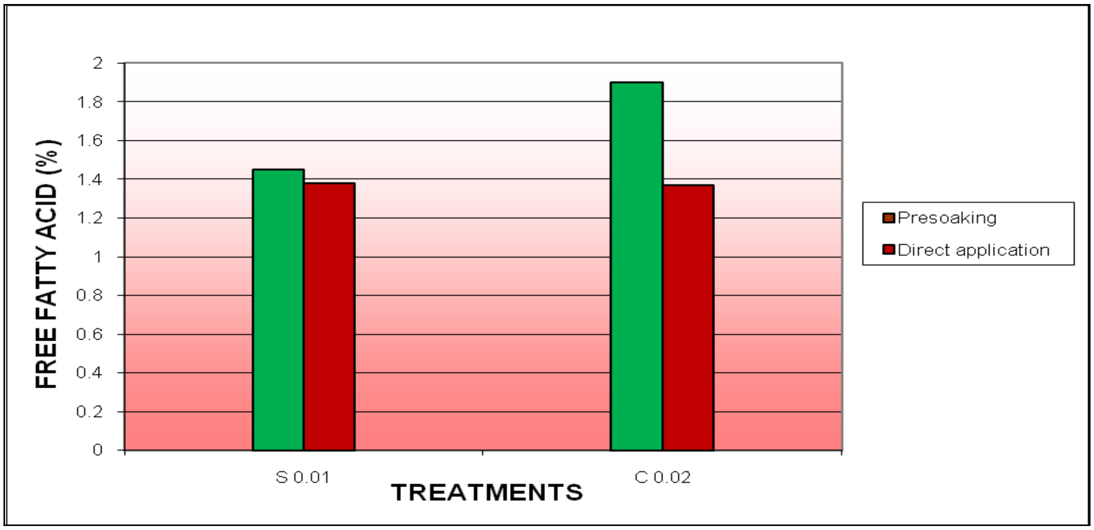
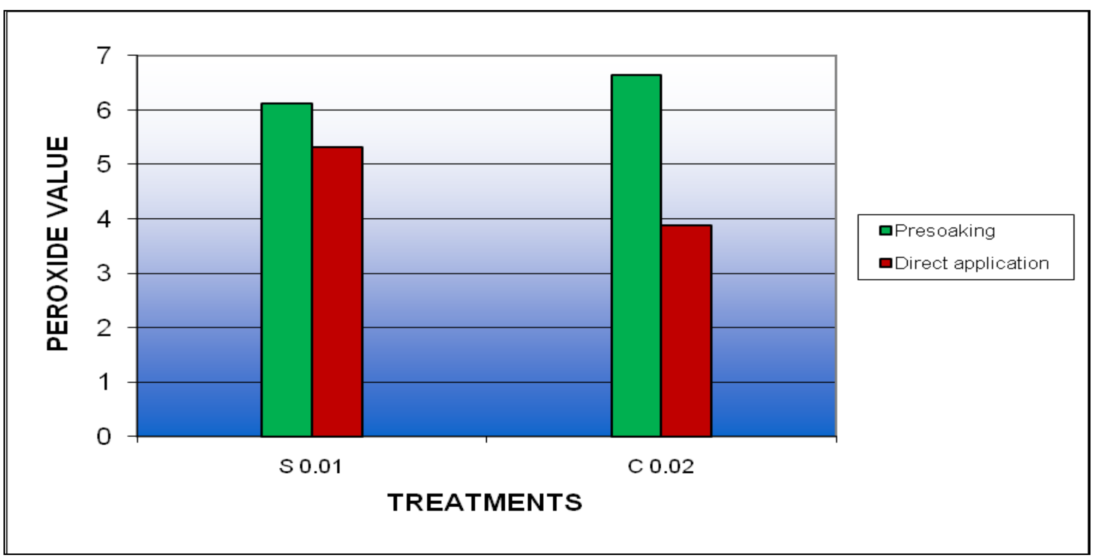


Fig 3b. Peroxide value



When the combination of antioxidants was used, there was no significant reduction in the free fatty acid and peroxide value of treated chips, hence there is no advantage in combining the antioxidants.

4.2.2.3. Sensory quality

When the acceptability of banana chips treated with different antioxidants was evaluated (Table12), chips prepared from slices presoaked in 0.01 % sodium ascorbate and 0.02 % tocopherol acetate recorded the highest score in terms of appearance (18.27) and the lowest was for chips which received presoaking application of 0.02 % curry leaf powder (6.45).

Chips prepared after direct addition of 0.01 % each of sodium ascorbate and curry leaf powder recorded the highest rank (16.83) for colour and the lowest rank for colour was for chips prepared from presoaked slices in combination of 0.01 % each of the three antioxidants (9.18).

Chips which were prepared after direct application of 0.01 % sodium ascorbate recorded the highest score (18.25) in terms of flavour and the lowest score for flavour was for chips prepared from slices presoaked in 0.02 % of curry leaf powder (8.55).

Direct addition of 0.01 % tocopherol in oil resulted in chips with highest score for texture (19.33) and the lowest score for texture was for chips which was prepared from presoaking application of 0.02 % each of sodium ascorbate and curry leaf powder (9.70).

Presoaking slices in a mixture of 0.01% sodium ascorbate and 0.02 % tocopherol acetate resulted in chips with highest score in terms of taste (18.5) and the lowest was for chips which received presoaking application of 0.02 % of sodium ascorbate and 0.01 % curry leaf powder (8.50).

Table 12. Effect of antioxidants on organoleptic quality of chips

Groups		Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Slices presoaked in antioxidants	I	S 0.01	14. 95	16.27	14.93	17.23	16.23	17.52
		T 0.02	17.75	16.70	15.90	16.63	17.38	16.15
		C 0.02	6.45	10.85	8.55	10.27	11.35	9.35
	II	S 0.02+C0.02	12.13	15.63	15.27	9.70	11.30	11.80
		S 0.02+C0.01	10.18	12.20	12.23	14.18	8.50	8.32
		T 0.02+C0.02	14.48	15.93	14.27	14.15	14.23	12.90
		T 0.02+C0.01	16.52	10.63	11.35	16.23	15.40	14.25
		S 0.02+T 0.02	17.13	15.02	16.00	14.70	11.30	16.15
		S 0.01+T 0.02	18.27	14.83	8.85	13.85	18.50	14.85
	III	S 0.01+T 0.01+ C 0.01	12.82	9.18	9.63	14.15	14.82	13.80
		S 0.01+T 0.01+ C 0.02	13.18	15.93	15.80	16.23	15.40	12.70
		S 0.02+T 0.01+ C 0.01	12.70	10.43	15.30	13.00	14.38	12.65
		S 0.02+T 0.02+ C 0.01	15.25	14.70	12.18	11.77	8.55	16.67
Antioxidants directly added to oil	I	S 0.01	15.35	16.70	18.25	16.50	17.13	18.05
		T 0.01	15.07	14.38	15.73	19.33	15.93	15.95
		C 0.02	16.08	14.70	16.00	13.00	15.57	14.85
	II	S 0.02+C0.02	10.77	15.02	14.13	14.70	14.38	13.45
		S 0.01+C0.01	13.60	16.83	15.55	13.85	14.82	15.65
		T 0.02+C0.01	12.40	10.80	10.18	11.77	12.77	10.48
		T 0.01+C0.02	12.52	13.18	14.63	15.95	14.90	13.35
		S 0.02+T 0.02	16.27	14.70	15.73	13.10	14.38	17.52
		S 0.01+T 0.02	15.93	10.85	15.90	10.27	14.82	15.95
	III	S 0.02+T 0.02+ C 0.02	16.77	15.60	14.13	9.95	17.18	16.08
		S 0.02+T 0.01+ C 0.01	7.82	12.20	15.55	14.18	15.57	12.18
		S 0.02+T 0.01+ C 0.02	13.48	15.60	15.27	11.77	11.35	10.20
		S 0.01+T 0.02+ C 0.02	14.68	10.80	12.23	15.95	14.38	10.25
	Control		15.45	10.45	14.80	15.95	16.38	16.92
	Assymp.sig.		0.000	0.004	0.000	0.000	0.000	0.000

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

Direct application of 0.02% curry leaf in oil produced chips with maximum score for flavour (18.25) and overall acceptability (19.00).

Among chips from presoaked slices, 0.01 % sodium ascorbate had highest score for colour(16.77),texture(17.23),taste (17.23) and overall acceptability(17.52).This higher acceptability may be due to superior chemical quality parameters.

0.02 % curry leaf which had better chemical quality among the directly added antioxidants resulted in higher organoleptic quality for texture(19),taste(18.57) and overall acceptability(17.52), hence can be recommended for improving the quality of banana chips.

In general, all group I antioxidants whether applied directly in oil or slices soaked in it had similar yield and oil uptake. When applied as presoaking ,they had similar moisture and integrity also. When applied directly in oil, they had similar shrinkage too.

When the quality of chips prepared using antioxidants was analyzed, it was seen that though not significantly different, untreated chips had higher yield due to increased moisture and oil uptake. Group I antioxidants had least oil uptake and untreated chips had highest oil uptake, irrespective of application method. Among the antioxidant groups, group III had highest oil uptake. There was no significant difference between groups in shrinkage ratio. Presoaking slices in 0.01 % sodium ascorbate resulted in lower free fatty acid value (1.45 mg KOH/g) and peroxide value(6.02 meq.O_2/Kg).Addition of group I,II&III antioxidants in oil resulted in lower free fatty acid content than untreated chips. Group I antioxidants resulted in low free fatty acid value and high iodine value when applied on slices and when added directly to oil.

Direct addition of 0.02 % curry leaf powder resulted in lowest oil uptake (30.25%), highest integrity (84.00 %), where as 0.01 % sodium ascorbate produced chips with least shrinkage (21.00 %) and moisture (0.22 %) ,but with maximum oil uptake(31.60 %). Direct addition of 0.02% curry leaf powder produced chips with least peroxide value(3.88) and highest iodine value(12.52)

Presoaking in 0.01 % sodium ascorbate had resulted in highest sensory score for texture (17.23),taste (17.23)and overall acceptability(17.52) among chips prepared from presoaked slices. Among the chips prepared after adding antioxidants,0.02 % curry leaf powder had highest sensory score for texture(19.00),taste(18.57) and overall acceptability

Direct addition of antioxidants to frying oil resulted in lower oil uptake and higher integrity compared to presoaking slices in antioxidants .Direct addition of group I and II antioxidants recorded lower moisture content compared to presoaking. Direct addition of antioxidants to oil resulted in less yield due to low oil uptake and moisture content ,compared to presoaking of slices in antioxidants. Direct addition of group I and II antioxidants gave lower free fatty acid value and peroxide value when compared to presoaking the slices in the same antioxidants.

4.3. STORAGE STABILITY AND ACCEPTABILITY OF ANTIOXIDANT TREATED BANANA CHIPS

4.3.1. Changes in physical quality

Physical parameters of treated chips like moisture, colour and texture were measured at regular intervals, after storing in two different packages viz., laminated pouch and LDPE pouch

A.1. Moisture of chips from presoaked slices

a. ***Storage in laminated pouches***

Treatment combinations showed significant differences in moisture content of chips stored in laminated pouches (Table 13).

When the chips prepared from slices presoaked in group I treatments were stored in laminated pouches, all the treatments had significantly lower moisture content than the untreated chips throughout the storage period. Untreated chips recorded the highest moisture content (1.19%) at 15 days after storage, 1.29% at 30 days, 1.63% at 45 days, 1.90% at 60 days, 2.00% at 75 days and finally a moisture content of 2.18% at 90 days of storage. The treatments within group I were always on par in moisture content. However, chips produced from slices presoaked in 0.02% curry leaf powder recorded the highest moisture content compared to other two chemical antioxidant treated chips through out the period of storage.

Among the group II treatments, the lowest moisture content was recorded by the chips made from slices treated with a combination of 0.02 % each of tocopherol acetate and curry leaf powder (0.85%) which was on par with all other treatments in the same group except untreated chips. This treatment and a combination of 0.02 % tocopherol acetate+0.01 % curry leaf powder maintained the lowest moisture content through out the period of storage. Chips produced from slices presoaked in a combination of 0.02% each of tocopherol acetate and curry leaf powder recorded moisture of 1.53% at 90 days after storage, which was on par with slices soaked in 0.02% tocopherol acetate and 0.01% curry leaf powder (1.51%).

When the effect of storage on treatments in group III was compared, the treatments were not significantly different from each other. However, the treatments were the lowest moisture content (0.89%) was recorded by the chips made from slices treated with a combination of 0.01% sodium ascorbate, 0.01 % tocopherol

Table 13. Moisture content(%) of chips prepared from presoaked slices during storage

Group	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	0.52	0.58	0.61	0.66	0.68	0.69	0.73	0.34	0.50	0.73	0.81	0.94	1.20
	T 0.02	0.46	0.54	0.58	0.64	0.66	0.78	0.91	0.60	0.73	0.88	1.04	1.24	1.43
	C 0.02	0.57	0.63	0.76	0.84	0.97	1.01	1.24	0.64	0.75	0.89	1.03	1.16	1.19
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.52	0.56	0.89	0.71	0.88	0.89	1.11	0.63	0.72	0.82	0.93	1.05	1.17
	CD	0.22	0.32	0.15	0.14	0.22	0.42	0.16	0.30	0.35	0.37	0.30	0.40	0.42
II	S 0.02+C0.02	0.91	1.11	1.30	1.46	1.63	1.86	1.96	0.97	1.13	1.26	1.43	1.58	1.72
	S 0.02+C0.01	1.21	1.42	1.67	1.72	1.80	1.89	2.11	0.99	1.23	1.43	1.53	1.64	1.78
	T 0.02+C0.02	0.73	0.85	0.96	1.09	1.27	1.37	1.53	0.90	1.03	1.17	1.24	1.36	1.50
	T 0.02+C0.01	0.80	0.90	1.02	1.15	1.29	1.38	1.51	0.68	0.76	0.85	0.99	1.16	1.32
	S 0.02+T 0.02	0.92	1.04	1.17	1.38	1.53	1.66	1.81	1.11	1.22	1.26	0.63	0.86	1.95
	S 0.01+T 0.02	0.94	1.16	1.31	1.40	1.57	1.70	1.88	1.42	1.13	1.79	1.80	0.89	2.10
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.92	1.12	1.05	1.34	1.42	1.65	1.82	1.00	1.25	1.42	1.57	1.72	1.88
	CD	0.11	0.33	0.24	0.13	0.52	0.18	0.26	NS	NS	NS	NS	NS	NS
III	S 0.01+T 0.01+ C 0.01	0.89	1.09	1.26	1.39	1.60	1.80	1.97	1.21	1.37	1.49	1.65	1.75	1.96
	S 0.01+T 0.01+ C 0.02	0.80	0.89	1.01	1.41	1.55	1.76	2.03	1.11	1.23	1.46	1.53	1.68	1.86
	S 0.02+T 0.01+ C 0.01	0.75	0.89	1.01	1.21	1.39	1.61	1.97	0.97	1.16	1.24	1.43	1.61	1.72
	S 0.02+T 0.02+ C 0.01	0.86	1.05	1.34	1.56	1.72	1.94	2.21	1.02	1.19	1.36	1.49	1.56	1.72
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.82	0.95	1.08	1.26	1.69	1.65	2.02	1.08	1.24	1.39	1.54	1.65	1.82
	CD	0.06	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	CD for groups	0.25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

acetate and 0.02 % curry leaf powder and chips treated with 0.02 % sodium ascorbate, 0.01 % tocopherol acetate and 0.01 % curry leaf powder. Chips treated with these two treatments had lowest moisture content from 45 days of storage till at the end of 90 days of storage. At 45 days after storage, the lowest moisture content was recorded by the chips made from slices treated with a combination of 0.02 % sodium ascorbate, 0.01 % tocopherol acetate and 0.01 % Curry leaf powder (1.21%) and chips treated with these antioxidant combination recorded the lowest moisture content of 1.39% at 60 days , 1.61% at 75 days and 1.97% at 90 days of storage.

Moisture content of all chips stored in laminated pouches, whether prepared from presoaked slices or untreated slices, showed a gradual increase in moisture content from 15 to 90 days after storage. The result is in agreement with the findings of Molla *et al*., (2009), who had stated that moisture of banana chips increases on storage irrespective of the packing material used.

When the storage stability was compared with respect to moisture content between different groups of antioxidants, there was no significant difference between groups. However, untreated chips recorded the highest moisture content throughout the period of storage.

b***. Storage in LDPE pouches***

When the moisture content of chips in group I was compared (Table 13), all the treatments had significantly lower moisture than untreated chips through out storage. But Group I antioxidants were on par regarding the moisture content. However 0.01 % sodium ascorbate maintained a lower moisture content through out storage. This may be due to the antioxidant action of ascorbic acid released to the system, which enhances the moisture removal from the slices to the oil. There was no significant difference between different antioxidants within group II and group III. There was no significant difference between different antioxidant groups for moisture content. It indicates that there is no use in combining antioxidants in order to reduce moisture content.

B.1.Moisture of chips prepared after adding antioxidants in oil

When the moisture of chips prepared after adding antioxidants was evaluated during storage, chips treated with group I antioxidants showed significantly lower moisture content compared to control in both the packages (Table 14.). Chips treated with 0.02% curry leaf retained low moisture content through out storage, when stored in laminated pouch. But in LDPE, chips treated with 0.01% sodium ascorbate had lowest moisture from 15-45 days, chips treated 0.01 % tocopherol acetate recorded the lowest moisture from 60-90 days. Chips stored in laminated pouch recorded comparatively lower moisture content at the end of storage.

At the end of storage period, untreated chips recorded 2.18% moisture in laminated pouch and 2.40% moisture in LDPE pouch. All the chips, in which group II were incorporated, had lower moisture content compared to control, if packed in any package. A combination of 0.01% Sodium ascorbate+ 0.02% Tocopherol acetate had higher moisture during almost all stages of storages, in laminated pouches and 0.02% each of sodium ascorbate and curry leaf powder recorded lowest moisture during later stages of 60-90 under laminated pouches. But in LDPE pouches, 0.01% Sodium ascorbate +0.02% Tocopherol acetate, which had high moisture in laminated pouches, recorded lowest moisture from 45-90 days.

In group III, untreated chips in both the packages recorded higher moisture content throughout storage period. Combination of 0.02% each of the three antioxidants, which recorded highest moisture (1.14 %) at initial stage, retained higher moisture of 1.33 and 1.44 during 15 & 30 days respectively. A combination of 0.02%Sodium ascorbate+0.01% tocopherol acetate+0.02% curry leaf powder had least moisture during later stages of 45-60 days. But when packed in LDPE pouches,

Table 14. Moisture content(%) of chips prepared after adding antioxidants in oil during storage

Grou	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	0.22	0.29	0.35	0.40	0.42	0.46	0.56	0.30	0.46	0.56	0.70	0.89	1.03
	T 0.01	0.27	0.31	0.36	0.45	0.49	0.57	0.61	0.31	0.46	0.58	0.66	0.80	0.98
	C 0.02	0.27	0.28	0.33	0.36	0.37	0.41	0.46	0.61	0.76	0.89	0.98	1.15	1.29
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.25	0.52	0.59	0.61	0.68	0.88	0.94	0.32	0.47	0.63	0.72	0.88	1.04
	CD	3.18	0.04	0.06	0.18	0.22	0.37	0.41	0.06	0.09	0.31	0.17	0.30	0.23
II	S 0.02+C0.02	0.49	0.54	0.65	0.77	0.90	0.97	1.21	0.70	0.82	0.93	1.03	1.21	1.35
	S 0.01+C0.01	0.53	0.61	0.72	0.84	0.97	1.12	1.30	0.49	0.67	0.77	0.87	1.00	1.10
	T 0.02+C0.01	0.55	0.63	0.75	0.87	1.01	1.17	1.33	0.98	1.16	1.24	1.43	1.62	1.72
	T 0.01+C0.02	0.64	0.39	0.88	1.01	1.16	1.32	1.43	1.06	1.22	1.34	1.46	1.55	1.71
	S 0.02+T 0.02	0.37	0.48	0.58	0.65	0.97	1.20	1.37	0.58	0.70	0.84	0.97	1.05	1.19
	S 0.01+T 0.02	0.83	0.95	1.11	1.32	1.47	1.65	1.74	0.63	0.68	0.77	0.84	0.92	0.99
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.57	0.85	0.83	0.92	0.96	1.19	1.28	0.67	0.81	0.94	1.06	1.22	1.37
	CD	0.11	0.13	0.13	0.28	0.22	0.35	0.19	0.06	0.09	0.24	0.13	0.23	0.18
III	S 0.02+T 0.02+ C 0.02	0.93	1.14	1.33	1.44	1.61	1.78	1.94	0.85	0.97	1.93	1.34	0.43	1.57
	S 0.02+T 0.01+ C 0.01	0.88	1.11	1.32	1.45	1.61	1.70	1.79	0.93	1.04	1.21	1.35	1.56	1.72
	S 0.02+T 0.01+ C 0.02	0.89	1.05	1.24	1.40	1.57	1.73	1.94	1.08	1.24	1.53	1.73	1.80	1.97
	S 0.01+T 0.02+ C 0.02	0.70	0.94	1.15	1.41	1.60	1.76	1.99	1.19	1.30	1.25	1.59	1.74	1.95
	Control	0.93	1.19	1.29	1.63	1.90	2.00	2.18	1.12	1.44	1.79	2.10	2.28	2.40
	Group Mean	0.85	1.11	1.18	1.26	1.59	1.82	1.85	1.01	1.17	1.29	1.42	1.53	1.68
	CD	0.09	0.11	0.12	0.18	NS	0.25	0.24	0.13	0.11	0.30	0.18	0.32	0.46
	CD for groups	0.25	0.18	0.21	0.32	0.35	0.41	0.36	0.28	0.30	0.31	0.30	0.32	0.33

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

0.02% each of the three antioxidants maintained lowest moisture from 15-90 days except at 45 days.

At the end, chips treated with 0.02 % sodium ascorbate+0.01 % tocopherol acetate+0.01% curry leaf and stored in laminated pouch recorded the lowest moisture content(1.79%) where as in the case of LDPE, chips treated with 0.02 % each of the three antioxidants recorded the lowest (1.57%) moisture content.

When different groups were compared, group III recorded significantly higher (1.85% in laminated pouch and 1.68 % in LDPE) moisture content than the other groups in both packages . Group I always had the lowest moisture content, hence retaining quality through out storage.

Moisture content of chips whether packed in any packaging material, showed a gradual increase during storage and this agrees with the result of (Molla *et al*.,2009), who had recorded a gradual increase in moisture and weight during storage. Moisture of chips packed inside a pouch is dependent on the relative humidity of the surroundings. The chips absorb moisture from the storage atmosphere and gains weight gradually. The result is in agreement with the findings of Rahman and Shams-Ud-Din (2003).

A.2. Colour of chips from presoaked slices

a. *Storage in laminated pouches*

When the effect of different antioxidants in group I on the yellowness index of banana chips was compared (Table 15) all the treated chips had an yellowness index ,which were significantly different and lower than untreated chips indicating that the colour of group I antioxidant treated chips gets faded during storage. When the effect of different antioxidants on the yellowness index of banana chips was

Table 15. Colour of chips from presoaked slices during storage

Group	Treatments	At the time of storage	Laminated pouch			LDPE pouch		
			Days after storage			Days after storage		
			30	60	90	30	60	90
I	S 0.01	108.66	89.07	94.34	98.45	100.96	85.25	103.98
	T 0.02	113.24	87.37	92.44	96.70	90.47	98.02	111.28
	C 0.02	117.55	82.64	95.23	87.70	98.86	99.59	109.24
	Control	120.40	112.39	104.19	109.42	109.80	104.83	113.54
	Group Mean	112.47	93.96	95.85	92.15	91.96	100.90	103.75
	CD	3.75	2.40	2.68	2.47	0.72	0.52	1.15
II	S 0.02+C0.02	122.19	101.79	113.62	112.83	87.43	112.22	116.72
	S 0.02+C0.01	118.35	106.13	111.92	111.08	112.57	104.83	86.89
	T 0.02+C0.02	117.43	104.23	113.49	114.08	105.24	102.68	102.02
	T 0.02+C0.01	96.76	104.83	111.79	112.33	97.17	110.61	101.43
	S 0.02+T 0.02	114.70	102.93	102.45	105.02	116.70	112.22	104.79
	S 0.01+T 0.02	117.81	114.10	107.15	103.45	106.30	101.93	97.07
	Control	120.40	112.39	104.19	109.42	109.80	104.83	113.54
	Group Mean	115.24	109.25	104.56	108.32	99.00	99.71	98.12
	CD	3.75	2.40	2.68	2.47	2.46	0.96	1.72
III	S 0.01+T 0.01+ C 0.01	127.81	113.15	113.49	104.83	94.19	90.55	94.75
	S 0.01+T 0.01+ C 0.02	114.94	115.80	111.79	102.93	94.40	94.66	90.86
	S 0.02+T 0.01+ C 0.01	113.27	109.46	102.85	114.10	98.29	96.60	107.52
	S 0.02+T 0.02+ C 0.01	108.41	112.11	101.15	112.20	99.16	98.02	109.06
	Control	120.40	112.39	104.19	109.42	109.80	104.83	113.54
	Group Mean	116.11	109.45	106.22	108.45	96.51	96.60	100.55
	CD	3.75	2.40	2.68	2.47	2.48	0.98	2.28
	CD for groups	2.53	3.22	2.85	2.75	14.38	NS	11.91

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

compared among the group II category, different treatments behaved differently during storage and chips made from slices treated with a combination of 0.02 % sodium ascorbate and 0.01 % curry leaf powder recorded an yellowness index closer to the colour of untreated chips at final stage of storage.

In group III, none of the treatments had consistent performance during storage. When groups were compared over different antioxidants, group II and III had yellowness index which was not significantly different from untreated chips. Roopa *et al*.,(2006) also reported the loss of original yellow colour and development of browning during storage.

b. ***Storage in LDPE pouches***

As in laminated pouch, yellowness index of chips prepared from presoaked slices and packed in LDPE pouch didnot show any constant change during storage(Table 15.). Yellowness index of chips which is similar to that of standard value at the end of storage can be treated as acceptable at the end of storage. When groups were compared over different antioxidants, yellowness index of group II (99.00) and III (96.51) were significantly on par with the standard value(109.8). During 60 days, there was no significant difference between different groups. But by the end of storage, group I had colour value (103.75) similar to that of standard value (113.54) thus making it highly acceptable.

B.2. Colour of chips prepared after adding antioxidants in oil

a. ***Storage in laminated pouches***

Yellowness index of chips prepared after adding antioxidant did not show any consistent change during storage (Table 16). Yellowness index of chips which retained the standard value (120.40) at the end of storage can be treated as acceptable at the end of storage.

Table 16.Colour of chips after adding antioxidants to oil during storage

Group	Treatments	At the time of storage	Laminated pouch Days after storage			LDPE pouch Days after storage		
			30	60	90	30	60	90
I	S 0.01	110.89	110.94	113.58	109.24	110.69	112.25	108.36
	T 0.01	129.44	110.43	110.93	107.49	104.20	91.99	114.98
	C 0.02	109.63	101.22	86.39	104.86	105.72	105.75	105.49
	Control	120.40	100.70	84.65	103.11	109.80	104.83	113.54
	Group Mean	116.65	105.38	96.59	109.11	105.38	96.59	109.11
	CD	3.75	0.72	0.73	0.73	0.72	0.73	0.73
II	S 0.02+C0.02	108.98	104.45	92.86	115.86	105.22	112.60	114.73
	S 0.01+C0.01	114.48	103.94	91.12	114.11	106.84	102.76	107.91
	T 0.02+C0.01	110.79	90.73	98.89	112.16	111.19	105.75	103.66
	T 0.01+C0.02	125.32	90.21	97.15	110.41	112.38	113.12	109.29
	S 0.02+T 0.02	106.31	105.97	106.62	106.37	93.92	102.13	110.11
	S 0.01+T 0.02	116.13	105.46	104.88	104.62	84.80	94.23	99.60
	Control	120.40	100.70	84.65	103.11	109.80	104.83	113.54
	Group Mean	113.66	99.08	105.14	110.89	99.08	105.14	110.89
	CD	3.75	2.84	2.46	2.46	2.84	2.46	2.46
III	S 0.02+T 0.02+ C 0.02	156.97	105.48	113.47	115.61	103.30	102.95	97.83
	S 0.02+T 0.01+ C 0.01	124.91	104.96	111.73	113.85	88.21	91.85	92.82
	S 0.02+T 0.01+ C 0.02	102.85	107.10	103.55	108.79	88.62	90.51	99.00
	S 0.01+T 0.02+ C 0.02	119.07	106.58	101.81	107.03	90.89	102.85	97.20
	Control	120.40	100.70	84.65	103.11	109.80	104.83	113.54
	Group Mean	125.97	110.34	106.24	109.47	110.34	106.24	109.47
	CD	3.75	2.48	2.48	2.48	2.48	2.48	2.48
	CD for groups	21.67	14.38	13.95	11.91	14.38	13.95	11.91

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

When the yellowness index of all treated chips is compared, they had yellowness index, which is higher than the colour of the untreated chips, except in group III, at the corresponding period. But they are closer to the original standard value accepted by the individual (120.40) during organoleptic analysis. This retention of more yellowness may be due to the protection given by the laminated material and the antioxidant applied.

b. *Storage in LDPE pouch*

In the first group chips made after adding 0.01 % tocopherol acetate retained an yellowness index of 114.98 which is closer to the standard value(113.54) (Table 16.). In group II, chips made after adding 0.02 % each of sodium ascorbate and tocopherol acetate retained an yellowness index of 110.11 at the end of storage, which is significantly on par with the standard value.

In group III, all treatments were having lower colour values compared to the chips made from untreated slices indicating its faded nature. The major factor affecting the yellowness index of chips is the packaging material.

The fading of the typical golden yellow colour of banana chips gradually and turning to pale yellow and white colour during storage was also reported by Ogazi (1986). Besides processing conditions, storage condition also affect the colour of chips. The main factor is light which gives a pale yellow colour to chips during storage due to oxidation. This result is supported by the findings of Adeniji(2005) who stated that banana chips packed in transparent polythene covers developed off flavor and colour due to accelerated lipid oxidation in presence of light. This may be the reason for less acceptable colour for chips stored in the transparent LDPE pouch than laminated pouch, where the chips is protected to a great extent from exterior illumination.

A.3. Texture of chips from presoaked slices

a. ***Storage in laminated pouch***

The hardness as indicated by force, of group I antioxidant treated chips was not significantly different from the untreated chips through out the storage period (Table 17). Though 0.01% sodium ascorbate treated chips had least hardness (5.92 N) at the initial stage, it had the highest hardness (8.43 N) during 90 days of storage. But 0.02 % curry leaf, which had highest hardness (6.17 N) at the time of preparation, exhibited least hardness (4.85 N) at 90 days of storage indicating its storage stability.

At 60 days after storage, there was no significant difference regarding hardness in group II antioxidants, and at 90 days, slices soaked in 0.02 % each of sodium ascorbate & tocopherol had lowest hardness (5.89 N).

In chips made from slices treated with group III antioxidants, chips made from untreated slices recorded the least hardness(5.43 N) followed by chips treated with 0.02 % sodium ascorbate 0.01 % tocopherol acetate and 0.01 % curry leaf powder (6.31 N) value by the end of storage.

Groups of antioxidants did not make any significant difference in hardness of chips.

The toughness of antioxidant treated chips was significantly different from the untreated chips towards the end of storage in the first group of treatments. Chips made from untreated slices recorded the lowest toughness at 30 days and it was the toughest at 60 days (7.23 Ns).

In group II, chips made from slices treated with 0.02% sodium ascorbate and 0.02% curry leaf powder recorded the lowest (2.89 Ns) toughness value at 90th day of storage.

In group III, all the treatments were on par with respect to toughness at 30 days. However 0.01 sodium ascorbate + 0.01 tocopherol acetate + 0.02 curry leaf had

Table 17.Texture of chips prepared from presoaked slices during storage

Group	Treatments	Laminated pouch											
		Hardness – Force (N)				Toughness- Area (Ns)				Crispness- count			
		Days after storage											
		0	30	60	90	0	30	60	90	0	30	60	90
I	S 0.01	5.92	8.67	7.38	8.43	1.98	3.25	3.93	3.73	5.25	3.50	6.36	6.45
	T 0.02	5.97	8.16	11.71	7.15	2.05	6.14	5.08	3.86	4.78	4.50	6.00	4.73
	C 0.02	6.17	7.60	6.39	4.85	1.69	2.27	3.15	2.71	4.22	4.47	5.57	6.75
	Control	5.64	8.99	9.95	5.43	1.18	2.05	7.23	5.03	4.32	3.93	3.85	4.22
	Group Mean	6.01	8.14	8.66	6.81	1.91	3.88	4.05	3.43	4.75	4.61	5.12	5.18
	CD	NS	NS	NS	NS	NS	1.14	2.88	1.94	NS	NS	1.00	2.96
II	S 0.02+C0.02	5.85	6.37	9.61	6.70	2.88	2.21	2.29	2.89	5.92	4.21	4.95	5.67
	S 0.02+C0.01	7.80	7.57	7.11	5.93	1.97	1.53	4.64	3.43	4.17	5.29	5.42	4.16
	T 0.02+C0.02	8.31	5.25	9.34	5.95	2.49	1.91	6.14	4.90	4.90	4.30	5.29	7.34
	T 0.02+C0.01	8.45	6.80	8.01	7.50	2.07	2.62	4.54	5.84	6.02	5.40	5.30	3.75
	S 0.02+T 0.02	6.88	7.30	6.42	5.89	1.75	2.18	2.17	4.30	6.05	3.35	4.15	4.75
	S 0.01+T 0.02	7.60	6.05	9.23	8.04	1.64	2.07	3.09	5.33	5.75	4.88	5.51	4.97
	Control	5.64	8.99	9.95	5.43	1.18	2.05	7.23	5.03	4.32	3.93	3.85	4.22
	Group Mean	7.31	6.55	8.29	6.67	2.13	2.08	3.81	4.44	5.68	4.95	4.90	6.82
	CD	1.47	3.24	NS	1.91	1.39	NS	2.91	2.13	1.75	2.18	1.89	NS
III	S 0.01+T 0.01+ C 0.01	5.25	8.67	8.39	7.05	2.26	1.75	3.44	5.21	5.06	4.57	4.88	6.14
	S 0.01+T 0.01+ C 0.02	7.97	6.39	8.20	8.25	1.75	1.64	2.93	4.70	6.20	4.78	4.57	5.69
	S 0.02+T 0.01+ C 0.01	7.78	9.37	8.81	6.31	1.64	2.83	3.36	6.21	5.69	4.22	4.78	4.57
	S 0.02+T 0.02+ C 0.01	8.98	6.95	6.74	6.70	2.73	2.25	4.33	4.73	5.69	5.92	4.22	4.42
	Control	5.64	8.99	9.95	5.43	1.18	2.05	7.23	5.03	4.32	3.93	3.85	4.22
	Group Mean	7.79	7.84	8.03	7.08	2.12	2.11	3.49	5.21	5.66	5.70	5.88	5.62
	CD	2.45	1.84	3.51	2.08	1.15	NS	3.02	1.31	1.33	1.22	NS	1.98
	CD for groups	1.52	NS	NS	NS	1.36	2.46	2.81	2.79	2.05	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

least toughness (1.64 Ns). This chips exhibited least toughness during 60 days (2.93 Ns) and 90 days (4.70 Ns).

Crispness of chips prepared from slices in presoaked in group I antioxidants were not significantly different during 30 days, as in the beginning of storage. At the end of storage, slices soaked in curry leaf 0.02 % had highest crispness (6.75) making it more crispy texture.

In group II, 0.02 % each of sodium ascorbate and tocopherol acetate had highest crispness at the time of storage(6.05). At 60 days 0.01 % sodium ascorbate +0.02 % tocopherol had highest (5.51) crispness. Chips made from slices treated with 0.02 % each of tocopherol acetate and curry leaf powder recorded highest crispness (7.34) at the final stage of 90 days also.

In group III, chips from sliced presoaked in 0.01% sodium ascorbate + 0.01% tocopherol acetate + 0.02% curry leaf had highest crispness of 6.20 at the time of storage. At the final stage, this was on par with the chips having highest crispness (6.14).

On comparing groups, they were on par regarding crispness value. However untreated chips had least crispness during storage indicating its low quality.

So by analyzing components of texture, it is understood that though treated chips did not make any difference in hardness and toughness, crispness of chips is improved by adding antioxidants, thus improving the crispness of banana chips.

Texture of treated chips in terms of crispness was retained during storage compared to control. This may be due to the combined effect of antioxidants and the barrier property of packing material used.

b. ***Storage in LDPE pouches***

When the effect of different antioxidants in group I on the hardness of banana chips was compared (Table 18.), there was no significant difference between

Table 18.Texture of chips prepared from presoaked slices and packed in LDPE during storage

group	Treatments	Hardness- Force (N)				Toughness - Area(Ns)				Crispness- count			
		Days after storage											
		0	30	60	90	0	30	60	90	0	30	60	90
I	S 0.01	5.92	7.20	3.70	8.04	1.98	4.54	3.55	6.43	5.25	5.29	5.59	7.63
	T 0.02	5.97	6.35	7.11	8.59	2.05	3.85	5.37	7.97	4.78	4.15	6.79	5.30
	C 0.02	6.17	6.50	6.50	9.55	1.69	4.45	4.72	8.41	4.22	4.67	4.74	8.70
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	6.01	7.16	6.90	8.95	1.91	2.88	5.08	5.98	4.75	4.61	5.12	5.18
	CD	2.43	NS	NS	NS	0.98	1.50	NS	NS	NS	NS	1.0	2.96
II	S 0.02+C0.02	5.85	7.10	3.39	9.86	2.88	4.80	3.29	6.44	5.92	4.63	5.45	5.25
	S 0.02+C0.01	7.80	4.49	7.71	9.05	1.97	4.97	2.61	5.13	4.17	5.00	6.30	6.43
	T 0.02+C0.02	8.31	5.65	7.42	8.14	2.49	3.78	3.31	4.22	4.90	4.42	7.45	5.63
	T 0.02+C0.01	8.45	5.68	6.40	6.73	2.07	2.99	5.62	4.30	6.02	4.33	5.34	5.04
	S 0.02+T 0.02	6.88	6.62	7.74	8.70	1.75	1.66	3.59	8.41	6.05	6.25	4.34	5.90
	S 0.01+T 0.02	7.60	7.16	8.16	10.08	1.64	2.45	4.05	7.82	5.75	3.63	4.76	6.17
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	7.31	6.50	6.76	8.64	2.13	2.01	3.89	5.98	5.68	4.95	4.90	6.82
	CD	1.47	1.40	3.69	NS	1.39	0.95	1.60	2.49	1.75	2.18	1.89	NS
III	S 0.01+T 0.01+ C 0.01	5.25	6.78	9.96	14.02	2.26	1.75	3.17	2.61	5.06	4.63	6.36	5.75
	S 0.01+T 0.01+ C 0.02	7.97	5.78	8.46	7.91	1.75	1.64	5.95	9.24	6.20	5.50	4.73	4.63
	S 0.02+T 0.01+ C 0.01	7.78	8.01	7.79	9.48	1.64	2.83	3.78	4.67	5.69	6.84	6.75	5.61
	S 0.02+T 0.02+ C 0.01	8.98	7.60	7.52	8.33	2.73	1.96	3.33	3.34	5.69	5.83	5.67	6.51
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	7.79	7.04	8.43	9.93	2.12	2.04	4.06	4.97	5.66	5.70	5.88	5.62
	CD	2.45	1.49	NS	4.22	1.15	1.09	NS	2.92	1.33	1.22	NS	1.98
	CD for groups	1.52	NS	NS	NS	1.36	NS	NS	NS	2.05	NS	NS	NS

S-Sodium ascorbate T- Tocopherol acetate C- Curry leaf powder treatments. Chips made slices soaked in 0.01 % sodium ascorbate had least hardness (3.70 N and 8.04 N) at 60 and 90days.

The combination of 0.02 % sodium ascorbate and 0.01 % curry leaf recorded the lowest hardness (4.49 N) in the second group at 30 days and chips of slices soaked in 0.02 % each of sodium ascorbate and curry leaf had least hardness (3.39 N) at 60 days. At 90 days all treatments were on par. Antioxidants with in group III were on par in case of hardness of chips at 60 days. A combination of 0.01 % sodium ascorbate, 0.01 % tocopherol acetate and 0.02 % curry leaf powder recorded the least hardness of 5.78 N and 7.91 N during 30 and 90 days.

When the efficiency of different groups was compared, there was no significant difference between the other different groups for hardness of chips. However, Group III produced the maximum hardness (9.93 N) at 90 days

Toughness of chips from presoaked slices in group I antioxidant during storage was not significant different during 60and 90 days though untreated chips had least hardness(5.40 Ns) at 90 days of storage.

In group II untreated chips maintained least toughness till 30 days of storage and at final stage this was on par with chips having least toughness 0.02% sodium ascorbate +0.01 curry leaf with toughness (5.13Ns).

In group III, untreated chips had least toughness at 30 days and chips from slices soaked in 0.01 % each of sodium ascorbate, tocopherol acetate and curry leaf had least toughness at 60 and 90 days.

There was no significant different between groups for toughness. It is clear that all the chips whether treated or not had same toughness.

When crispness of chips prepared from group I antioxidants are compared ,there was no significant difference between treatments during 30 days. At 60 and 90 days, untreated chips had lowest crispness (3.85) and (4.22) respectively. At the end of storage, chips from slices soaked in 0.02 % curry leaf powder had maximum (8.70) crispness.

In group II antioxidants, all treatments were on par regarding crispness at the end of storage.

In case of chips prepared from slices presoaked in group III antioxidants, texture was uniform during 60 days. Slices soaked in 0.02 % sodium ascorbate+ 0.01 % tocopherol acetate+0.01 % curry leaf powder produced chips with maximum crispness during 30 and 60 days, whereas chips produced by presoaking slices in 0.02 % sodium ascorbate+ 0.02 % tocopherol acetate+0.01 % curry leaf powder had maximum crispness(6.51) at the end of storage. There was no significant difference between different groups for crispness.

B.3. Texture of chips prepared after adding antioxidants in oil

a. ***Storage in laminated pouches***

At 30 days after storage, chips treated prepared after adding 0.02 % curry leaf had the least hardness of 6.67 N (Table 19.) At the final stage of 90 days, untreated chips had least hardness (5.43 N). When the effect of group II antioxidants on storage was studied, all the treatments were having less hardness compared to untreated chips (8.99 N). At final stage, as in group I, untreated chips had least hardness. All the group III treatments were on par regarding hardness; making clear that group III treated chips had similar hardness. All the treatments, whether I,II or III, had similar hardness at 60 days. There was no significant difference between different treatments, indicating that by treating antioxidants, hardness is not seen affected at 60th day of storage.

Group I antioxidant treated chips had similar toughness at 30 and 90 days. At 60 days0.01 % tocopherol treated chips showed least toughness (3.02 Ns). Regarding group II treatments, they were not significantly different during 90 days and group III treatments were on par at 60 days of storage. As in hardness, all groups had similar toughness, indicating that they had uniform toughness.

Table 19. Texture of chips after adding antioxidants in oil during storage

Group	Treatments	Laminated pouch											
		Hardness- Force (N)				Toughness- Area (Ns)				Crispness- count			
		Days after storage											
		0	30	60	90	0	30	60	90	0	30	60	90
I	S 0.01	6.56	6.78	6.49	6.25	1.95	3.27	3.84	4.14	5.75	3.50	6.70	4.97
	T 0.01	5.45	9.38	5.99	8.63	2.68	3.47	3.02	5.22	5.41	4.80	4.50	5.09
	C 0.02	8.99	6.67	7.50	9.21	2.88	3.19	3.16	5.04	6.32	4.93	5.23	6.07
	Control	5.64	8.99	9.95	5.43	1.18	2.05	7.23	5.03	4.32	4.05	5.56	4.05
	Group Mean	6.99	7.61	6.65	8.02	2.50	3.30	3.34	4.79	5.83	3.5	4.8	4.93
	CD	2.60	2.07	NS	3.05	NS	NS	2.73	NS	1.29	NS	2.14	NS
II	S 0.02+C0.02	6.73	7.26	8.33	6.79	1.97	5.85	7.26	8.33	6.79	2.88	7.26	8.33
	S 0.01+C0.01	6.97	6.18	6.69	8.98	2.49	2.16	3.26	4.81	4.88	4.59	5.24	6.02
	T 0.02+C0.01	6.50	5.9	8.83	10.47	1.71	4.64	4.33	4.54	4.57	5.29	5.46	5.20
	T 0.01+C0.02	6.95	7.38	9.00	7.12	2.19	6.14	7.23	5.03	4.78	5.39	5.88	7.03
	S 0.02+T 0.02	5.77	7.22	8.87	8.30	1.59	4.54	5.21	6.19	4.22	4.15	5.34	5.72
	S 0.01+T 0.02	5.25	6.84	7.28	9.27	2.21	2.17	3.55	4.33	5.92	3.70	4.94	5.83
	Control	5.64	8.99	9.95	5.43	1.18	3.09	2.85	5.99	4.32	4.67	4.33	6.86
	Group Mean	6.36	6.79	8.16	8.48	2.03	2.05	7.23	5.03	4.98	4.05	5.56	4.05
	CD	2.80	2.07	4.11	3.05	0.86	3.78	4.40	NS	1.83	NS	NS	NS
III	S 0.02+T 0.02+ C 0.02	6.10	7.51	10.26	9.59	1.53	2.67	2.73	1.82	4.17	1.69	2.14	2.49
	S 0.02+T 0.01+ C 0.01	5.50	7.50	10.24	9.06	1.91	7.97	7.50	10.24	9.06	1.75	9.06	1.75
	S 0.02+T 0.01+ C 0.02	6.70	7.63	8.29	6.61	2.82	3.44	5.11	5.58	6.92	3.30	7.00	7.36
	S 0.01+T 0.02+ C 0.02	6.54	7.20	8.67	8.14	1.66	2.27	3.88	3.55	6.45	3.63	5.93	5.30
	Control	5.64	8.99	9.95	5.43	1.18	3.18	5.37	7.17	4.32	4.25	4.70	6.79
	Group Mean	6.21	7.45	9.36	8.34	1.98	3.37	3.41	6.47	5.61	5.05	4.67	6.00
	CD	1.75	NS	NS	NS	1.13	2.05	NS	5.03	1.79	4.05	5.56	4.05
	CD for groups	2.52	NS	NS	NS	1.36	NS	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

Regarding crispness, none of the treatments showed significant difference between them during 30 days. At 90 days also, there was no significant difference between antioxidants regarding crispness with in group I and II. In group I, 0.02% curry leaf treated chips had highest crispness, indicating its crispness. In group III, untreated chips had highest crispness during 30 days with crispness value of 4.25.

When groups were compared, there was no significant difference between them. By comparing all the textural parameters, all groups had similar hardness, toughness and crispness. So when chips prepared after adding antioxidants directly in oil are stored in laminated pouches, its textural quality is not changed from untreated chips at all.

b. ***Storage in LDPE pouches***

Group I antioxidant treated chips were not significantly different during 30 and 60 days and at 90 days, chips treated with 0.01% sodium ascorbate had least hardness, which had least hardness in the laminated pouch also (Table 20.).

Group II antioxidant treated chips had uniform hardness during 60 and 90 days. As in laminated pouches, group III antioxidant treatments resulted in chips with uniform hardness throughout storage.

Group I antioxidant treated chips were significantly different in toughness during 30 and 60 days only. The untreated chips had least toughness (1.41 Ns) at 30 days and 0.01% tocopherol treated chips had least toughness (2.85 Ns) during 60 days. The condition was same in laminated pouch also. It is understood that group I antioxidant treated chips had similar toughness in both the packages.

In group II, untreated chips had least toughness of 1.41 and 3.28 during 30 and 60 days respectively and at 90 days, chips treated with 0.01% each of sodium

Table 20. Texture of chips; prepared after adding antioxidants in oil; packed in LDPE pouch during storage

Group	Treatments	LDPE pouch											
		Hardness- Force (N)				Toughness- Area (Ns.)				Crispness- count			
		Days after storage											
		0	30	60	90	0	30	60	90	0	30	60	90
I	S 0.01	6.56	7.15	5.97	6.75	1.95	3.05	5.21	6.21	5.75	4.59	6.33	6.70
	T 0.01	5.45	6.95	11.02	8.48	2.68	4.90	2.85	4.17	5.41	5.30	4.49	4.67
	C 0.02	8.99	6.85	7.08	9.07	2.88	4.48	3.60	5.67	6.32	3.70	5.67	6.75
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	6.99	7.10	6.89	7.75	2.50	4.16	3.87	5.60	5.83	5.06	5.47	6.45
	CD	2.60	NS	NS	1.56	2.17	1.35	1.69	NS	NS	NS	NS	1.57
II	S 0.02+C0.02	6.73	5.65	8.25	8.87	1.97	2.73	3.78	7.82	6.79	3.30	5.49	10.38
	S 0.01+C0.01	6.97	5.18	6.36	7.94	2.49	2.17	3.33	3.87	4.88	3.43	4.70	4.38
	T 0.02+C0.01	6.50	6.37	4.62	9.09	1.71	3.54	9.24	5.95	4.57	5.84	5.17	6.25
	T 0.01+C0.02	6.95	5.98	7.43	9.54	2.19	3.25	4.67	7.13	4.78	6.17	5.49	6.10
	S 0.02+T 0.02	5.77	6.92	6.54	8.42	1.59	1.79	6.3	7.97	4.22	3.79	5.69	4.76
	S 0.01+T 0.02	5.25	8.87	7.77	9.85	2.21	3.86	3.33	5.67	5.92	5.71	4.32	5.76
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	6.36	6.27	6.45	8.98	2.03	3.74	4.01	6.69	4.98	3.98	5.47	6.79
	CD	2.80	1.40	NS	NS	0.86	2.08	1.15	3.26	NS	1.49	NS	4.22
III	S 0.02+T 0.02+ C 0.02	6.10	6.73	5.64	7.82	1.53	2.05	4.55	4.63	4.17	4.73	5.76	4.42
	S 0.02+T 0.01+ C 0.01	5.50	6.43	6.72	8.59	1.91	1.69	4.11	2.62	9.06	6.10	4.57	4.77
	S 0.02+T 0.01+ C 0.02	6.70	6.65	5.64	7.98	2.82	2.18	3.27	3.37	6.92	5.17	4.42	9.10
	S 0.01+T 0.02+ C 0.02	6.54	5.83	6.92	8.74	1.66	2.07	3.77	4.28	6.45	3.80	5.56	10.58
	Control	5.64	5.47	9.30	8.54	1.18	1.41	3.28	5.40	4.32	3.93	3.85	4.22
	Group Mean	6.21	5.62	6.79	8.95	1.98	3.88	4.96	5.61	5.61	5.35	6.10	6.10
	CD	1.75	NS	NS	NS	1.13	NS	NS	NS	NS	NS	1.80	2.41
	CD for groups	2.52	NS	NS	NS	1.36	1.95	NS	NS	NS	NS	NS	4.27

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

ascorbate + curry leaf showed least toughness (3.87 Ns). Group III treated chips did not show any significant difference in toughness.

Regarding crispness, group I treated chips had no significant difference at 30 and 60 days of storage. At final stage, 0.02% curry leaf treated chips had highest count value indicating its high crispness. At 90 days, chips treated with 0.02% sodium ascorbate + curry leaf had maximum crispness (10.38) among group II antioxidants and chips treated with 0.01% sodium ascorbate + 0.02% tocopherol acetate + 0.02% curry leaf had maximum crispness (10.58) among group III antioxidants.

Groups behaved similarly in all textural properties. However untreated chips had least toughness, but they had least crispness. As crispness is one of the major factors affecting quality of banana chips, treated chips can be considered better in textural properties.

4.3.2.1. Changes in chemical quality

Free fatty acid value, peroxide value and iodine value of the stored chips were measured at fortnightly intervals.

A.1.Free fatty acid value of chips from presoaked slices

a. ***Storage in laminated pouches***

Chips prepared from presoaked slices showed significant difference in free fatty acid content, when stored in laminated pouches (Table. 21).

When the effect of antioxidants within Group I,II and III treatments were compared, all the treatments had significantly lower free fatty acid content than the untreated chips through out storage period. Untreated chips recorded highest free fatty acid content. Treatments under group I did not show any consistent results

Table 21. Free Fatty Acid content (mg KOH/g)of chips prepared from presoaked slices during storage

Group	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	1.45	2.82	3.75	4.11	5.83	6.40	7.11	2.50	2.45	3.75	5.40	6.05	7.00
	T 0.02	1.80	2.64	2.79	3.88	5.87	6.30	7.68	2.45	2.90	3.43	5.45	6.10	7.30
	C 0.02	1.90	2.39	3.50	4.29	4.88	6.21	7.18	2.15	2.40	3.30	5.25	5.70	8.50
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.80	2.88	4.30	6.15	6.46	8.00
	Group Mean	1.72	2.63	3.35	4.09	5.52	6.30	7.32	2.47	2.08	4.32	5.50	6.33	7.55
	CD	0.09	0.14	0.09	0.17	0.25	0.20	0.63	NS	NS	NS	0.89	0.40	0.80
II	S 0.02+C0.02	2.00	2.47	3.10	3.60	4.76	5.69	6.83	2.00	2.65	3.30	4.30	5.65	6.60
	S 0.02+C0.01	1.90	2.56	2.97	3.31	4.72	5.69	6.90	2.21	3.10	3.70	5.30	5.80	7.10
	T 0.02+C0.02	2.02	2.37	2.98	3.46	4.62	5.78	6.97	2.30	3.20	3.85	5.10	6.18	7.36
	T 0.02+C0.01	2.15	2.67	3.41	4.19	5.48	5.99	7.28	1.90	2.50	4.05	5.35	6.25	7.30
	S 0.02+T 0.02	1.90	2.71	3.25	4.63	5.49	6.20	7.20	2.38	3.78	4.69	5.40	6.40	7.38
	S 0.01+T 0.02	1.85	2.20	3.69	4.58	5.83	6.75	7.42	2.40	3.40	4.30	5.20	5.80	6.85
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.80	2.88	4.30	6.15	6.46	8.00
	Group Mean	1.97	2.49	3.23	3.96	5.14	6.01	7.09	2.13	3.52	4.25	5.29	6.19	6.96
	CD	0.19	0.36	0.14	0.21	0.42	0.28	0.47	NS	NS	NS	1.16	NS	0.53
III	S 0.01+T 0.01+ C 0.01	1.90	2.54	3.24	4.79	5.13	6.23	7.80	2.50	3.20	4.05	5.38	6.25	7.65
	S 0.01+T 0.01+ C 0.02	1.82	2.10	3.72	4.16	5.20	6.10	7.45	2.70	3.20	4.30	5.25	6.51	7.45
	S 0.02+T 0.01+ C 0.01	2.08	2.47	3.38	4.52	5.44	6.46	7.49	2.70	3.70	3.60	6.65	7.30	7.00
	S 0.02+T 0.02+ C 0.01	1.88	2.61	3.29	4.51	5.16	6.25	7.85	2.50	3.00	4.00	4.90	6.13	7.30
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.80	2.88	4.30	6.15	6.46	8.00
	Group Mean	1.92	2.43	3.41	4.50	5.23	6.26	7.65	2.60	3.28	3.98	5.54	6.55	7.35
	CD	0.06	0.13	0.41	0.61	0.32	0.29	0.54	NS	NS	NS	NS	NS	NS
	CD for groups	0.31	0.42	0.50	0.81	0.82	0.63	0.48	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

during storage period. FFA content of chips which received 0.02 % curry leaf powder recorded the lowest FFA content at 15 and 60 days after storage (2.39 mg KOH/g) and 4.88 mg KOH/g respectively). FFA content of chips prepared from slices presoaked in 0.02% tocopherol recorded the lowest FFA at 30 and 45 days after storage (2.79 mg KOH/g and 3.88 mg KOH/g). Slices soaked in 0.01 % sodium ascorbate recorded lowest FFA (7.11 mg KOH/g) at 90 days.

FFA content of chips which received a combination of 0.01% sodium ascorbate and 0.02 % tocopherol acetate was lowest at 15 days of storage (2.20 mg KOH/g), which was on par with chips which received combinations of 0.02 % sodium ascorbate and 0.02 % curry leaf powder (2.47 mg KOH/g), 0.02 % sodium ascorbate and 0.01 % curry leaf powder (2.56 mg KOH/g), and 0.02 % tocopherol acetate and 0.02 % curry leaf powder (2.37 mg KOH/g). These three treatments were the lowest and on par in free fatty acid content except during 45 days of storage. Chips which received a combination of 0.02% each of sodium ascorbate and curry leaf powder recorded the lowest FFA content of 6.83 mg KOH/g at 90 days after storage which was on par with all other treatments in the group except the combination of 0.01 % sodium ascorbate and 0.02 % tocopherol acetate (7.42 mg KOH/g).

In group III, chips which received a combination of 0.01% sodium ascorbate, 0.01% tocopherol acetate and 0.02 % curry leaf powder recorded the lowest FFA content (2.10 mg KOH/g) at 15 days of storage. Chips from slices soaked in this combination of antioxidants maintained the lowest FFA during all periods of storage, except at 30 and 60 days.

FFA content of all chips, whether treated or untreated, showed a gradual increase during storage period. By reaction with oxygen, fat degrades to a mixture of volatile aldehydes, ketones and free fatty acids. This reaction occurs at smoke point of oil and during storage, this reaction is activated in the presence of light, there by increasing the fatty acid value during storage. Kapila *et al*., (2005) also reported a reduction in free fatty acid value due to addition of antioxidants. Laminated pouches give better protection from moisture and light thereby delaying the development of rancidity. Islam and Shams-ud-din (2003) also stated that the chemical quality of chips stored in laminated pouch was the best during storage.

Comparing the effect of storage on free fatty acid content of treated chips, group II treatments recorded lowest FFA content compared to other groups, even though all of them were on par. Antioxidants in group I & group II did not show any consistent results.

b. *Storage in LDPE pouches*

Free fatty acid content of all chips soaked in group I and II antioxidants were similar to that of untreated chips from 15-45 days of storage (Table 21.) Group III antioxidant treated chips had similar free fatty acid value with that of untreated one through out storage. Chips produced from slices soaked in group I antioxidants had similar free fatty acid value from 60-90 days of storage though they were significantly lower in free fatty acid value than untreated chips. At final stage of storage, all group III antioxidant treated chips had become similar to untreated chips in free fatty acid content. But in laminated pouches, treated chips had lower FFA content than untreated chips and have better quality retention. Lamination helps in preventing the entry of moisture or light thus reducing the quality degradation of chips. This result agrees with the findings of Molla et al (2009).

There was no significant difference between different groups for FFA value. It indicates that efficiency of antioxidants in reducing the free fatty acid value of chips is not improved by combination of different antioxidants. Free fatty acid value of all the treated and untreated chips is increased during storage, resulting in increased rancidity. Formation of free fatty acids is an important measure of rancidity of chips as it is formed due to hydrolysis of triglycerides and may get promoted by reaction of oil with moisture. FFA content went on increasing with the increase in storage period for all the samples as reported by Rehman (2003).

B.1. Free fatty acid value of chips prepared after adding antioxidant in oil

a. ***Storage in laminated pouches***

When the effect of antioxidants on the FFA value of chips was compared(Table 22.) within group I, 0.02 % curry leaf powder produced chips with lowest value(2.70 mg KOH/g)at 15 days after storage to 6.11 mg KOH/g at 90 days after storage. Through out storage, all treatments had significantly lower FFA value than that of chips made from untreated slices.

Regarding group II treatments, slices treated with 0.01 % sodium ascorbate and 0.02 % tocopherol acetate produced chips with lower FFA value (6.23 mg KOH/g) at the end of 90 days of storage.

In group III antioxidants, all the treatments produced chips with significantly lower FFA content compared to the chips made from untreated slices. However chips made from slices soaked in a mixture of 0.02 %sodium ascorbate+0.01 % tocopherol acetate+0.02 % curry leaf powder recorded lowest free fatty acid content of 6.23 mg KOH/g at the end of 90 days of storage.

When the storage stability of chips prepared from different groups of antioxidants were compared, all groups had significantly lower FFA value compared to the chips from untreated slices throughout storage. This result is supported by Rehman (2003),who stated that antioxidant treated chips had a lower free fatty acid value than control during storage. Amongst groups, group I recorded the lowest values for free fatty acid through out storage. Combination of antioxidants did not

Table 22 . Free fatty acid content (mg KOH/g) of chips prepared after adding antioxidants in oil during storage

Group	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	1.38	2.65	2.99	3.52	5.05	6.15	6.70	2.80	3.90	5.08	5.60	6.45	7.50
	T 0.01	1.30	2.82	2.80	3.18	4.44	5.78	6.48	2.50	3.58	4.50	5.18	5.93	6.15
	C 0.02	1.37	2.70	2.85	3.20	4.33	5.05	6.11	2.30	3.30	4.03	5.10	5.80	6.10
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.60	3.48	4.30	5.50	6.86	8.00
	Group Mean	1.35	2.72	2.88	3.29	4.61	5.66	6.43	2.60	3.64	4.61	5.39	6.36	6.88
	CD	0.14	0.06	0.16	0.39	0.55	0.44	0.73	1.04	1.61	1.35	0.63	0.75	1.53
II	S 0.02+C0.02	1.47	2.67	3.11	4.10	4.82	5.50	6.80	2.40	3.20	4.60	5.45	6.40	7.15
	S 0.01+C0.01	1.30	2.56	2.82	3.23	4.90	5.55	6.33	2.60	3.30	4.25	5.20	6.15	7.15
	T 0.02+C0.01	1.22	2.85	3.24	3.96	4.52	5.63	6.80	2.69	3.40	3.90	4.40	6.10	7.40
	T 0.01+C0.02	1.84	2.35	2.92	3.30	4.69	5.30	6.46	2.30	3.11	4.35	5.65	6.25	7.30
	S 0.02+T 0.02	1.45	2.39	2.91	4.06	5.20	5.81	6.50	2.50	3.15	4.55	5.60	6.40	7.80
	S 0.01+T 0.02	1.41	2.70	3.05	4.20	4.90	5.60	6.23	2.45	3.60	4.35	5.45	6.35	7.65
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.67	3.48	4.30	5.50	6.46	7.85
	Group Mean	1.45	2.58	3.01	3.81	4.84	5.56	6.52	2.47	3.13	4.02	5.29	6.18	7.08
	CD	0.13	0.06	0.16	0.39	0.55	0.44	0.73	NS	NS	NS	NS	NS	NS
III	S 0.02+T 0.02+ C 0.02	1.41	2.54	3.17	4.28	4.98	5.47	6.65	2.60	3.60	4.55	5.09	6.60	7.30
	S 0.02+T 0.01+ C 0.01	1.66	2.22	2.76	3.49	4.49	5.46	6.73	2.71	3.85	4.60	5.00	6.50	7.00
	S 0.02+T 0.01+ C 0.02	1.34	2.44	2.96	3.48	4.28	5.14	6.23	2.70	3.20	3.70	4.85	6.30	7.00
	S 0.01+T 0.02+ C 0.02	1.61	2.57	2.95	3.50	5.49	5.89	6.51	2.20	3.00	3.50	4.30	5.55	6.30
	Control	2.14	3.26	5.06	6.52	7.34	8.07	8.98	2.75	3.48	4.30	5.15	6.46	7.70
	Group Mean	1.50	2.44	2.96	3.69	4.81	5.49	6.53	2.55	3.20	3.95	5.08	6.08	7.29
	CD	0.06	0.40	0.10	0.10	0.15	0.18	0.54	NS	NS	NS	NS	NS	NS
	CD for groups	0.31	0.42	0.50	0.81	0.82	0.63	0.48	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

result in reduction of free fatty acid value, compared to single application. This may be due to the antagonistic action of the various antioxidants used.

b. ***Storage in LDPE pouches***

When the effect of antioxidants on the free fatty acid content of chips were compared,(Table 22.) chips made from slices treated with 0.02 % curry leaf powder recorded the lowest FFA through out storage ranging from 2.30 mg KOH/g at 15 DAS to 6.10 mg KOH/g at 90 DAS. At 75 and 90 days after storage all the treated chips had significantly lower free fatty acid value compared to untreated chips. It is clear that chips prepared after adding 0.02 % curry leaf powder had better storage stability compared to other treatments.

In group II, and group III, there was no significant difference between the treatments within the group through out the storage period. There was no significant difference among the groups for free fatty acid content.

A.2.Peroxide value of chips from presoaked slices

a. ***Storage in laminated pouches***

When the effect of antioxidants within Group I treatments were compared,(Table 23) all the treatments had significantly lower peroxide value than the untreated chips through out storage. Untreated chips recorded highest peroxide value through out storage period ranging from 9.22 meq. O_2/Kg at 15 days, increased to 13.63 meq. O_2/Kg at 90 days after storage. Peroxide value of chips prepared from slices presoaked in 0.01% sodium ascorbate recorded the lowest peroxide value through out storage ranging from 6.32 meq. O_2/Kg at 15 days to 9.82 meq. O_2/Kg at 90 days after storage.

Table 23.Peroxide value(meq.O_2/Kg) of chips from presoaked slices during storage

Group	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	6.02	6.32	6.76	7.99	8.48	8.95	9.82	6.53	7.79	8.39	9.15	9.73	10.85
	T 0.02	7.13	7.89	8.87	10.02	10.47	10.70	11.35	8.10	8.91	9.67	10.77	11.35	11.70
	C 0.02	6.64	7.19	7.95	8.32	9.24	9.58	10.13	7.02	7.50	8.03	8.69	9.19	10.54
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	6.93	8.65	8.53	9.26	9.59	9.91	10.38	7.61	8.23	8.79	9.49	10.25	11.15
	CD	1.62	1.46	1.22	1.18	1.47	1.31	1.41	NS	NS	2.14	1.83	1.49	1.23
II	S 0.02+C0.02	4.85	7.89	9.34	9.34	10.01	10.70	11.62	7.00	7.98	8.74	9.14	9.49	10.54
	S 0.02+C0.01	6.70	7.64	8.01	9.20	10.01	10.87	11.54	5.81	6.67	7.03	7.80	8.95	9.65
	T 0.02+C0.02	6.54	7.22	8.09	8.70	9.15	9.76	10.41	7.29	7.79	8.19	8.98	9.62	9.94
	T 0.02+C0.01	5.92	7.98	9.54	10.65	11.08	11.43	11.99	8.30	8.89	9.49	9.85	10.71	11.25
	S 0.02+T 0.02	5.97	7.51	8.36	9.04	10.05	10.97	11.53	7.54	8.14	8.77	9.93	11.27	11.94
	S 0.01+T 0.02	6.17	7.15	8.19	8.57	9.12	9.24	10.32	7.30	7.81	8.48	9.05	9.49	10.55
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	6.02	9.05	9.20	9.62	10.07	10.49	11.09	7.89	7.40	7.99	8.63	9.35	10.18
	CD	1.96	1.79	1.14	1.26	1.29	1.01	1.23	1.52	0.96	1.98	1.29	1.54	1.37
III	S 0.01+T 0.01+ C 0.01	5.85	6.39	7.60	8.58	9.10	10.01	11.10	7.29	7.87	8.46	8.96	9.48	10.01
	S 0.01+T 0.01+ C 0.02	6.80	7.60	8.32	9.20	9.87	10.37	10.85	7.03	7.39	7.80	8.64	9.38	10.17
	S 0.02+T 0.01+ C 0.01	8.31	9.10	9.64	10.33	11.02	11.59	12.18	7.00	7.37	8.15	9.23	9.62	10.34
	S 0.02+T 0.02+ C 0.01	8.45	8.91	9.74	10.52	11.54	12.09	12.57	6.94	7.26	7.79	8.11	8.45	10.12
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	7.35	9.36	9.87	10.43	10.82	11.23	11.65	7.19	7.56	8.01	9.27	9.89	11.61
	CD	1.40	2.01	1.96	2.09	1.59	1.46	1.36	NS	NS	NS	NS	NS	NS
	CD for groups	2.31	2.24	2.05	1.97	1.88	1.93	1.89	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C- Curry leaf powder

In group II, Peroxide value of chips which received a combination of 0.01% sodium ascorbate and 0.02 % tocopherol acetate recorded the lowest (7.15 meq. O_2/Kg) peroxide value at 15days, 8.57 meq. O_2/Kg at 45 days, 9.12 meq. O_2/Kg at 60 days, 9.24 meq. O_2/Kg at 75 days and finally with a value of 10.32 meq. O_2/Kg at 90 days after storage.

Peroxide value of chips which received a combination of 0.01% each of the three antioxidants recorded the lowest peroxide value in group III from 15 to 75 days of storage. At 90 days after storage, this was on par with the lowest treatment of 0.01 % Sodium ascorbate+ 0.01 % Tocopherol acetate+ 0.02 %Curry leaf powder with a peroxide value of 10.85 meq. O_2/Kg.

Peroxide value of different groups showed significant difference from untreated chips. Untreated chips had highest peroxide value from 45-90 days of storage. Rehman(2003) also reported a reduction in peroxide value of untreated chips compared to control during storage. Krokida *et al*., (2001) also observed an increase in peroxide value during storage. Other groups were on par in peroxide value. However group I showed lowest peroxide value and group II showed highest peroxide value.

b. ***Storage in LDPE pouches***

When the peroxide value of treatments within group I were evaluated, there was no significant difference between them upto 45 days of storage (Table 23). From 60 to 90 days of storage, all the treated chips had significantly lower peroxide values than the chips made from untreated slices. Chips made from slices treated with 0.02 % curry leaf powder had the lowest value (10.54 meq.O_2/Kg) at final stage.

In group II, treated chips varied in peroxide values through out storage from untreated chips. Chips prepared from slices presoaked in 0.02% sodium ascorbate +0.01 % curry leaf powder maintained lowest peroxide value throughout storage(5.81 meq O_2/Kg at 15 days of storage and 9.65 meq O_2/Kg at 90 days of storage.).

There was no significant difference between different antioxidants in group III, however the lowest value was recorded by chips made from slices treated with a combination of 0.01 % each of the three antioxidants through out storage.

There was no significant difference between different groups and untreated ones for peroxide value. However untreated chips maintained a higher peroxide value through out storage which is in agreement with Rehman, (2003) who stated that peroxide value increases during storage. Sophia *et al*.,(2006) also reported a reduction in peroxide value due to addition of antioxidants.

B.2. Peroxide value of chips prepared after adding antioxidants in oil

a. ***Storage in laminated pouches***

When the effect of directly added antioxidants within Group I treatments were compared, (Table 24) all the treatments had significantly lower peroxide value than the untreated chips through out storage. Untreated chips recorded a peroxide value of 9.22 meq. O_2/Kg at 15 days, increasing to 13.63 meq. O_2/Kg at 90 days after storage. Among the other three chemicals, peroxide value of chips prepared after adding 0.02% curry leaf recorded the lowest peroxide value of 4.40 meq. O_2/Kg at 15 days of storage , increasing finally to 8.22 meq. O_2/Kg at 90 days after storage.

When the effect of antioxidants within Group II treatments was compared, all the treatments had significantly lower peroxide value than the untreated chips through out storage. Though the treatments with in group were on par, chips produced after adding 0.02% each of sodium ascorbate and curry leaf powder acetate recorded lowest peroxide value (9.11 meq. O_2/Kg) at the end of the storage period.

Table 24.Peroxide value (meq O_2/Kg) of chips prepared after adding antioxidants in oil; during storage

Grou	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	5.31	6.65	7.00	7.90	8.55	8.76	9.02	7.28	8.16	8.67	9.34	9.89	10.28
	T 0.01	6.22	7.29	8.16	8.67	9.54	10.29	10.84	7.05	7.45	7.79	8.11	8.45	9.7
	C 0.02	3.88	4.4	6.18	7.04	7.89	8.12	8.22	6.96	7.33	7.76	8.56	9.31	9.61
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	5.13	6.12	6.87	7.23	7.46	7.56	7.99	7.61	8.23	8.79	9.49	10.25	11.15
	CD	3.61	2.66	2.05	1.89	1.52	1.39	1.11	NS	NS	2.14	1.83	1.49	1.23
II	S 0.02+C0.02	6.60	6.94	7.23	7.79	8.12	8.45	9.11	7.34	7.63	8.29	8.84	9.85	10.39
	S 0.01+C0.01	6.58	7.03	7.50	8.03	8.70	9.19	10.12	6.94	7.26	7.79	8.11	8.45	9.11
	T 0.02+C0.01	6.73	6.96	7.13	7.76	8.56	9.31	9.96	7.13	7.46	8.56	9.31	9.96	10.44
	T 0.01+C0.02	6.72	7.00	7.98	8.74	9.14	9.49	9.99	7.17	7.14	9.00	9.03	9.95	10.36
	S 0.02+T 0.02	5.51	5.82	6.67	7.03	7.80	8.95	9.45	5.82	6.67	7.03	7.80	8.95	9.83
	S 0.01+T 0.02	6.93	7.49	7.74	8.29	8.85	9.85	10.60	7.27	7.54	8.71	9.05	10.24	10.20
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	6.51	7.11	7.37	8.15	8.19	8.67	8.82	6.89	7.40	7.99	8.63	9.35	10.18
	CD	1.23	2.66	2.05	2.76	1.52	1.39	1.11	1.52	0.96	1.98	1.29	1.54	1.37
III	S 0.02+T 0.02+ C 0.02	5.80	6.22	7.52	7.99	8.79	9.32	10.34	7.03	7.49	8.03	8.69	9.19	10.12
	S 0.02+T 0.01+ C 0.01	6.61	7.2	8.19	8.84	9.71	9.98	10.59	7.50	8.02	8.90	9.84	10.73	11.35
	S 0.02+T 0.01+ C 0.02	8.41	8.6	9.48	9.73	10.13	10.54	11.20	8.42	9.15	9.44	10.33	10.75	12.67
	S 0.01+T 0.02+ C 0.02	6.33	6.92	7.42	7.70	8.41	8.66	9.62	8.19	9.08	9.65	11.01	11.90	12.31
	Control	6.88	9.22	9.70	10.71	11.60	12.76	13.63	8.49	9.52	10.33	12.03	12.71	13.79
	Group Mean	6.79	7.87	7.93	8.56	9.11	9.25	9.67	8.19	8.56	9.01	10.27	9.89	11.61
	CD	1.52	2.02	1.98	1.86	1.66	1.73	1.68	NS	NS	NS	NS	NS	NS
	CD for groups	2.31	2.24	2.05	1.97	1.88	1.93	1.89	NS	NS	NS	NS	NS	NS

S - Sodium ascorbate T –Tocopherol acetate C-Curry leaf powder

When the effect of storage of antioxidants within Group III treatments was compared, all the treatments had significantly lower peroxide value than the untreated chips through out storage. Treatments with in group III showed significant variation among them in peroxide value. Among the treated combinations, 0.01% sodium ascorbate + 0.02% tocopherol acetate + 0.02% curry leaf showed lower peroxide value during all stages except at 15 days.

b. ***Storage in LDPE pouches***

When the effect of antioxidants on the peroxide value in group I was compared,(Table 24) there was no significant difference between the treatments within the group upto 30 days of storage. After 60 days till the end of storage, all the treatments had significantly lower peroxide value than untreated chips. Chips made from slices treated with 0.02 % curry leaf powder recorded the lowest value(9.61 meq. O_2/Kg) at the end of storage ,which was on par with the other treatments in the group except that of untreated chips (13.79 meq. O_2/Kg)

In the group II, chips treated with 0.02 % each of sodium ascorbate and Tocopherol acetate recorded the lowest peroxide value(5.82 meq. O_2/Kg)at 15 days of storage, 6.67 meq. O_2/Kg at 30 days, 7.03 meq. O_2/Kg at 45 and 7.80 meq. O_2/Kg at 60 days. Chips prepared with 0.01 % each of sodium ascorbate and curry leaf powder recorded the lowest peroxide value (9.11 meq. O_2/Kg) at the end of storage.

In group III, chips made from slices treated with a combination of 0.02 % sodium ascorbate,0.02 % tocopherol acetate and 0.02 % curry leaf powder recorded the lowest peroxide value through out storage ,ranging from 7.03 meq. O_2/Kg at 15 DAS and 10.12 at 90 DAS. All the treatments had a significantly lower peroxide value than the untreated chips. This agrees with the findings of Kapila *et al*., (2005) and Rehman (2003), where they had found an increased peroxide value in untreated chips. Roopa *et al*., (2006) stated that there is an increase in the peroxide value of chips during storage.

A**.3.Iodine value of chips from presoaked slices**

When iodine value of chips prepared from presoaked slices during storage was compared, in group I, the treated chips had higher iodine value through out storage (Table 25.). During later stages of 60 – 75 days, curry leaf 0.02% had highest iodine value, which was favourable for retention of quality during storage. But there was no significant difference between chips stored in LDPE pouches.

Group II antioxidant treated chips showed significant difference during 75 days of storage, in LDPE pouch. None of the chips packed in laminated pouches, showed superior or inferior performance through out storage. But in LDPE pouches, chips treated with 0.02% each of sodium ascorbate and curry leaf powder had highest iodine value, during the other stages of observation, though they were statistically on par.

Group III antioxidant treated chips showed no significant difference for iodine value, when stored in laminated pouches. But in LDPE, chips showed significant difference only during 45 and 60 days of storage. Chips prepared form slices presoaked in 0.01% sodium ascorbate +0.01% tocopherol acetate + 0.02% curry leaf powder had an iodine value, higher than untreated chips, thus showing its better performance. 0.01% sodium ascorbate +0.01% tocopherol acetate + 0.02% curry leaf powder had comparatively higher iodine value in both the packages.

When groups were compared, there was no significant difference between groups for iodine value, through out storage period.

Table 25. Iodine value of chips, prepared from presoaked slices, during storage

Group	Treatments	At the time of storage	Days after storage											
			Laminated pouch						LDPE pouch					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	11.61	10.26	10.01	9.77	9.01	8.77	8.44	10.93	10.67	9.87	9.59	8.37	8.10
	T 0.02	11.69	10.60	10.27	9.94	9.42	8.72	8.19	10.85	10.01	9.57	8.12	7.52	7.35
	C 0.02	11.63	10.62	10.06	9.88	9.69	9.15	8.13	10.22	9.84	9.15	9.00	8.75	7.14
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	11.22	9.95	9.85	8.76	9.12	8.68	7.32	10.12	9.93	9.17	8.75	8.23	7.01
	CD	1.52	0.85	0.74	0.62	1.12	0.75	1.01	NS	NS	NS	NS	NS	NS
II	S 0.02+C0.02	11.85	10.04	9.71	9.31	8.60	7.77	6.84	10.75	10.07	9.82	9.16	8.59	7.62
	S 0.02+C0.01	11.68	10.67	9.32	8.69	7.71	6.99	6.17	9.22	9.1	8.41	7.79	7.55	6.61
	T 0.02+C0.02	11.72	9.91	9.83	8.82	8.02	7.41	7.05	8.72	8.45	7.88	7.12	6.69	6.03
	T 0.02+C0.01	12.03	9.14	8.75	8.37	7.89	7.12	6.73	8.83	8.51	8.16	7.81	7.57	7.44
	S 0.02+T 0.02	12.09	9.85	9.55	9.34	8.44	7.27	6.83	9.18	9.04	8.63	8.18	7.42	6.84
	S 0.01+T 0.02	11.97	9.31	8.85	8.51	8.16	7.81	7.35	9.25	9.03	8.01	7.19	6.95	6.17
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	10.36	9.82	9.22	8.57	8.14	7.06	6.55	9.70	9.27	8.77	8.13	7.41	6.83
	CD	1.63	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.83	NS
III	S 0.01+T 0.01+ C 0.01	12.14	10.22	9.87	9.64	9.24	8.80	8.02	10.23	10.06	9.69	9.13	8.35	8.02
	S 0.01+T 0.01+ C 0.02	10.74	10.59	10.41	10.18	9.66	9.40	9.12	10.74	10.48	10.22	9.75	9.40	9.12
	S 0.02+T 0.01+ C 0.01	10.79	8.57	8.39	8.13	7.71	7.53	7.36	9.02	8.80	8.23	8.09	7.91	7.36
	S 0.02+T 0.02+ C 0.01	10.63	10.36	10.12	9.91	9.72	9.17	8.62	10.45	10.20	9.72	9.37	9.09	8.62
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	10.18	9.85	9.11	9.33	8.32	8.14	7.12	10.12	9.88	9.46	9.08	8.69	7.58
	CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.75	1.83	NS	NS
	CD for groups	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

B.3.Iodine value of chips prepared after adding antioxidant in oil

When the effect of group I antioxidants on iodine value of chips prepared after adding antioxidants in oil was compared (Table 26.), all the treated chips stored in laminated pouch recorded significantly higher value than the untreated chips. This is a favourable character for all the treated chips. During later stages of 60-90 days, the entire group I treated chips were having similar iodine value. However, treatment with 0.02% curry leaf powder recorded the highest iodine value through out storage period. But there was no significant difference between chips stored in LDPE pouch for iodine value except at 75 days. It is evident that LDPE was not at all effective in maintaining the superiority of treated chips, which is expressed as increased iodine value. Even then untreated chips had lowest iodine value through out storage.

In group II antioxidants, iodine value of chips, prepared after adding antioxidants in oil, did not exhibit any significant difference except at 75 days, when stored in LDPE pouches. But in laminated pouches, iodine value showed significant difference from 15-60 days and during later stages of 75- 90 days, they were on par. In group II and III, there was no significant difference between chips stored in both the packages for iodine value, at the end of storage.

Group III antioxidant treated chips, when stored in laminate pouches, exhibited uniform iodine value, through out storage. However untreated chips had lowest iodine value, which is a poor quality parameter for chips. There was no significant difference for iodine value of chips when stored in LDPE also.

On comparing the group means, except group I antioxidants, the other two groups did not show any steady performance during storage. In group I, chips showed a better performance when packed in laminated pouches, by giving a higher iodinevalue.

Table 26. Iodine value of chips prepared after adding antioxidants in oil during storage

Grou	Treatments	At the time of storage	Laminated pouch						LDPE pouch					
			Days after storage						Days after storage					
			15	30	45	60	75	90	15	30	45	60	75	90
I	S 0.01	11.49	10.34	9.83	9.16	9.00	8.89	8.77	10.32	10.03	9.77	9.54	9.05	8.77
	T 0.01	12.19	11.41	10.21	9.72	9.35	8.93	8.35	11.00	10.58	10.01	9.53	9.11	8.32
	C 0.02	12.52	11.98	11.18	10.77	10.30	9.85	9.00	11.52	11.00	10.15	9.88	9.12	8.52
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	11.22	10.26	8.50	9.32	9.15	8.81	7.93	10.11	9.52	9.23	8.26	7.97	7.66
	CD	1.22	1.20	1.31	1.49	1.77	2.01	2.20	NS	NS	NS	NS	1.87	NS
II	S 0.02+C0.02	11.67	8.76	8.23	7.54	7.39	7.27	7.15	8.95	8.27	7.75	7.17	6.40	5.51
	S 0.01+C0.01	11.92	8.83	8.30	7.83	7.40	7.01	6.73	9.33	9.15	8.60	8.15	7.34	6.93
	T 0.02+C0.01	11.12	8.18	7.86	7.43	7.12	7.03	6.72	9.15	8.85	8.23	7.11	6.75	5.96
	T 0.01+C0.02	12.11	7.25	7.07	6.82	6.17	5.97	5.51	10.12	9.97	9.36	8.69	8.25	7.29
	S 0.02+T 0.02	11.95	8.78	8.57	8.06	7.54	7.37	6.93	10.01	9.91	9.50	9.02	8.11	7.69
	S 0.01+T 0.02	12.00	9.22	8.62	7.39	5.98	5.36	5.13	9.58	9.27	8.95	8.57	7.87	7.23
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	11.25	8.86	8.11	8.12	7.83	6.33	5.55	9.58	8.54	8.41	7.37	6.76	6.36
	CD	1.55	1.20	1.31	1.49	1.77	NS	NS	NS	NS	NS	NS	1.59	NS
III	S 0.02+T 0.02+ C 0.02	10.82	10.28	8.81	9.37	8.68	7.05	6.61	10.02	9.79	9.39	8.45	7.47	7.05
	S 0.02+T 0.01+ C 0.01	10.51	9.80	8.85	8.41	7.37	6.04	5.96	9.98	9.71	9.31	8.60	7.77	6.73
	S 0.02+T 0.01+ C 0.02	11.74	11.23	10.46	9.62	8.78	8.47	7.29	9.01	8.67	8.17	7.71	7.35	6.83
	S 0.01+T 0.02+ C 0.02	10.34	9.99	9.68	9.09	8.24	7.50	6.03	9.75	9.34	9.08	8.69	7.50	7.35
	Control	10.01	9.69	9.03	8.77	8.19	7.04	6.70	10.01	9.87	9.12	8.56	7.11	6.32
	Group Mean	10.85	9.55	8.51	8.54	8.15	7.12	6.47	9.53	9.09	8.47	7.68	7.31	6.47
	CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	CD for groups	NS	1.85	1.86	1.75	1.92	NS	NS	2.16	1.99	1.97	2.00	1.79	NS

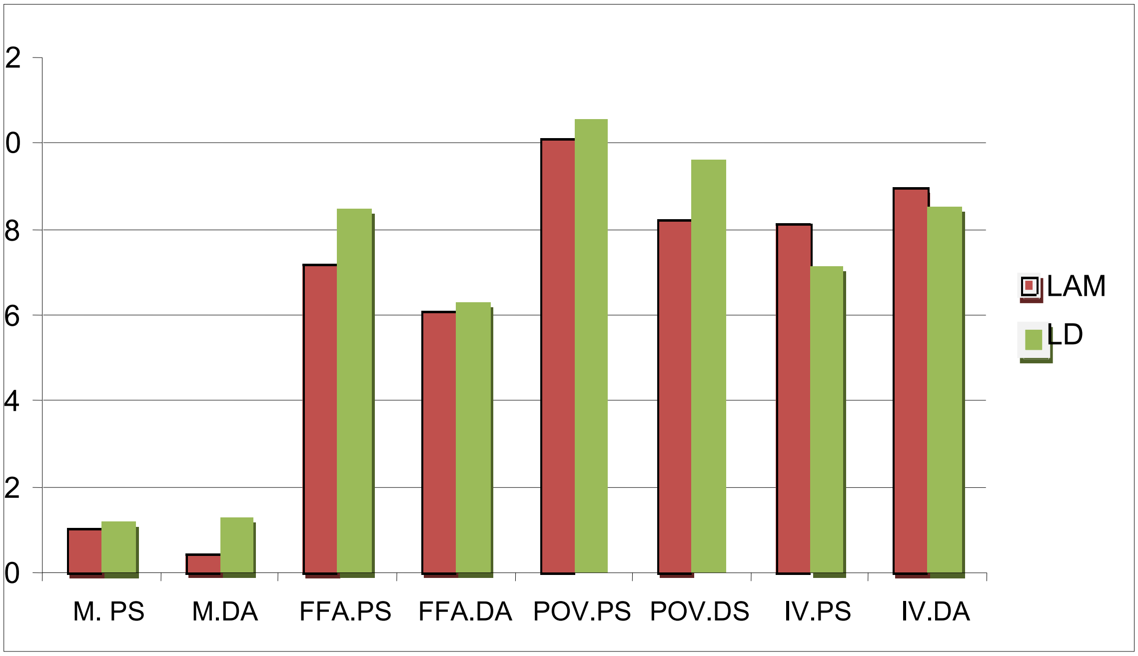
S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

In general, when the chemical quality of treated chips was evaluated, their performance was always superior to that of untreated ones. Rancidity which occurs due to the production of hydro peroxides, free fatty acids and other free radicals is effectively controlled by the addition of the antioxidants. Among the different antioxidants tried,0.02 % curry leaf powder gave superior results in terms of low free fatty acid value, low peroxide value and high iodine values through out storage in the direct application method. Since this natural product gave superior results than the two commercially available antioxidants tried, it can be considered as the best antioxidant having storage stability for controlling rancidity of banana chips. 0.01 % sodium ascorbate gave better result in the presoaking method and its performance was poor in direct application method. This may be due to the thermo liable nature of ascorbic acid. In the presoaking method, the antioxidant, ascorbic acid gets enough time to get incorporated into the slices thus avoiding the natural destruction.

4.3.2.a. Effect of packaging materials over period of storage

Moisture and oxygen are the two major physical factors which enhance the development of oxidative and hydrolytic rancidity .The chemical quality parameters like free fatty acid value and peroxide value indicate rancidity in chips. Moisture content, free fatty acid and peroxide value gradually increase during storage. Molla *et al*., (2009) also stated that moisture of banana chips increases on storage. This gradual increase is influenced by different factors including packaging materials. An efficient packaging material should prevent the increase in these quality parameters in storage of any deep fried product. Hence the efficiency of two different packing materials on quality parameters of chips was compared over time. 0.02 % curry leaf powder, which was identified as the best antioxidant in direct application method was selected for the comparison of packaging materials. In both the methods, moisture content was less in laminated pouch compared to LDPE pouch at the end of storage (Fig 4.) This clearly indicates the superiority of laminated pouch over LDPE

Fig 4. Quality parameters at the end of storage



M.PS- Moisture content (presoaking method)
M.DA- Moisture content (Direct application method)
FFA.PS-Free fatty acid value (presoaking method)
FFA.DA-Free fatty acid value (Direct application method)
POV.PS-Peroxide value (presoaking method)
POV.DA- Peroxide value (Direct application method)
IV.PS-Iodine value (presoaking method)
IV.DA- Iodine value (Direct application method)

Lam- Laminated pouch
LD - LDPE pouch

pouch in storing banana chips. The chemical quality parameters like free fatty acid value and peroxide value increase and iodine value decreases during storage of chips. The free fatty acid value and peroxide value are less and iodine value is high in laminated pouch compared to chips packed in LDPE pouch (Fig.4.). Islam and Shams-ud-din (2003) and Onyejugbu and Olorunda (1995) also reported that LDPE is a not a suitable packing material to store banana chips. Roopa *et al*., (2006) also reported a reduced acceptability of chips stored in LDPE pouches during storage.

4.3.3. Changes in sensory quality

4.3.3.a. *Appearance*

Banana chips which received a presoaking treatment of 0.01 % sodium ascorbate+0.02%tocopherol acetate recorded the highest score for appearance(18.27) (Table 27.) at 15 days of storage and the lowest rank for appearance was recorded by a combination of 0.02% sodium ascorbate and 0.01 % each of tocopherol acetate and curry leaf powder directly added in the frying oil(7.82). At 30 and 45 days ,chips from slices presoaked in 0.01 %each of the three antioxidants, recorded the highest score for appearance. At 60 and 75 days of storage, chips prepared after adding 0.02 % curry leaf had maximum score for appearance.

Among the chips prepared from presoaked slices, which were packed in LDPE pouches, chips prepared from slices presoaked in 0.02 % tocopherol acetate, which was having highest (18.10)score for appearance, retained the highest score during 60 and 90 days of storage. Among the chips, prepared after adding antioxidants in oil, direct addition of 0.01 % sodium ascorbate resulted in chips with highest score for appearance during 30(17.85) and 75(18.30) days of storage. Chips prepared by adding 0.02 % each of three antioxidants had higher score for appearance, at 60 days (17.02).At 90 th day 0.02 % curry leaf powder treated chips had highest appearance(16.60)

Table 27. Appearance of treated chips during storage

Group	Treatments	Laminated pouch						LDPE pouch					
		Days after storage						Days after storage					
		15	30	45	60	75	90	15	30	45	60	75	90
Presoaking of slices in antioxidants	S 0.01	14.95	8.02	8.32	11.52	15.77	11.55	15.00	13.52	7.03	9.73	16.40	11.90
	T 0.02	17.75	17.15	17.95	11.12	16.52	13.75	18.10	13.00	15.38	18.13	16.38	16.55
	C 0.02	16.45	12.93	13.18	16.75	12.85	14.10	6.65	12.80	4.97	10.85	9.15	14.73
	S 0.02+C0.02	12.13	12.52	11.65	14.56	14.57	13.05	11.80	13.98	14.40	13.88	14.23	15.25
	S 0.02+C0.01	10.18	17.30	16.42	15.73	10.20	16.92	10.48	16.17	17.08	15.35	14.40	12.48
	T 0.02+C0.02	14.48	13.23	12.23	17.52	16.38	15.18	14.25	11.73	13.85	13.70	15.10	13.10
	T 0.02+C0.01	16.52	17.80	17.65	11.12	14.93	19.15	16.42	11.85	12.05	14.30	13.10	13.15
	S 0.02+T 0.02	17.13	12.60	12.88	11.48	10.50	13.32	16.50	17.40	11.15	15.30	14.75	15.25
	S 0.01+T 0.02	18.27	9.10	8.65	8.73	11.50	12.10	17.55	10.57	10.70	11.00	10.52	12.48
	S 0.01+T 0.01+ C 0.01	12.82	18.42	18.65	10.58	14.50	14.60	12.90	12.05	4.68	15.45	11.93	12.55
	S 0.01+T 0.01+ C 0.02	13.18	17.73	17.95	11.46	14.93	15.73	12.70	17.40	17.73	14.23	13.68	13.15
	S 0.02+T 0.01+ C 0.01	12.70	12.77	12.55	12.59	13.75	12.48	13.77	12.10	16.55	14.52	14.07	15.07
	S 0.02+T 0.02+ C 0.01	15.25	15.25	15.48	12.23	8.40	17.02	14.85	15.20	16.73	15.40	15.88	12.48
Direct application of antioxidants to frying oil	S 0.01	15.35	16.35	15.70	15.19	16.38	15.43	14.45	17.85	16.25	11.65	18.30	13.60
	T 0.01	15.07	18.05	18.63	12.12	15.15	18.07	14.73	12.57	9.93	17.02	15.32	13.50
	C 0.02	18.08	16.30	16.15	18.52	18.55	18.18	16.15	12.07	17.38	16.93	16.70	16.60
	S 0.02+C0.02	10.77	13.25	13.10	17.82	14.63	13.48	10.63	13.52	17.27	10.63	12.57	15.07
	S 0.01+C0.01	13.60	15.75	16.33	13.12	15.20	12.85	13.55	16.40	17.52	14.48	11.63	12.55
	T 0.02+C0.01	12.40	11.63	11.70	16.75	12.88	11.02	14.55	11.75	13.05	14.82	9.95	14.40
	T 0.01+C0.02	12.52	17.98	17.52	17.16	14.55	13.13	12.30	15.90	18.50	12.98	13.35	13.02
	S 0.02+T 0.02	16.27	13.10	13.68	12.24	15.35	10.98	16.10	15.02	16.98	12.95	15.82	15.07
	S 0.01+T 0.02	15.93	10.55	11.20	16.43	13.40	12.75	16.48	16.95	10.80	16.33	15.50	12.55
	S 0.02+T 0.02+ C 0.02	16.77	16.50	16.05	12.41	14.98	12.80	17.15	14.73	16.02	17.02	14.32	16.55
	S 0.02+T 0.01+ C 0.01	7.82	12.55	13.35	12.22	14.38	13.40	8.07	17.20	15.15	14.57	13.23	13.60
	S 0.02+T 0.01+ C 0.02	13.48	9.02	9.27	11.12	11.43	12.27	13.02	13.15	14.85	11.23	13.75	14.73
	S 0.01+T 0.02+ C 0.02	14.68	13.38	13.23	10.12	12.23	15.90	14.45	10.55	17.85	15.80	14.80	15.07
	Control	15.45	12.77	12.55	12.54	16.52	14.40	15.40	12.55	14.18	14.77	15.18	16.55
	Assym. Sig.	0.002	0.000	0.014	0.002	0.006	0.022	0.009	0.000	0.000	0.000	0.002	0.004

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

4.3.3.1.b.*Flavour*

Among the chips packed and stored in laminated pouches, chips prepared after adding 0.01% sodium ascorbate obtained maximum score (18.25) for flavour during 15^{th} day only (Table 28.). Chips from slices soaked in 0.02% tocopherol acetate + 0.01% curry leaf powder had maximum score (19.05 and 19.2) during 30 and 60 days respectively. Direct application of 0.02% each of sodium ascorbate and tocopherol acetate recorded maximum score for flavour (16.42) during 45 days after storage.

Direct application of 0.02% curry leaf powder recorded maximum score (19.9 and 19.3) during 75 and 90 days respectively. Compared to direct application, presoaking slices and packed in laminated pouches gave inferior score for flavour during organoleptic scoring. This confirms the results of physical and chemical analysis of treated chips.

As in laminated pouch, direct application of 0.01% sodium ascorbate gave maximum score (19.08) for flavour only on 15 days, in LDPE also. Presoaking slices in 0.02% sodium ascorbate + 0.01% curry leaf powder scored maximum (17.10) for flavour during 30 days. Presoaking in 0.02% each of sodium ascorbate and curry leaf scored maximum rank (19.8 and 23.42) during 45 and 75 days respectively. Presoaking 0.02% curry leaf powder had maximum (19.5) score at the final stage of storage.

Untreated chips packed in LDPE pouch scored least during 75 and 90 days (8.55 and 7.52 respectively) and the scores were higher for chips packed in laminated pouches compared to those in LDPE pouches. This confirms the results of chemical analysis of treated chips.

Table 28. Flavour of treated chips during storage

Group	Treatments	Laminated pouch						LDPE pouch					
		Days after storage						Days after storage					
		15	30	45	60	75	90	15	30	45	60	75	90
Presoaking of slices in antioxidants	S 0.01	14.93	10.48	10.25	11.57	15.65	8.52	15.65	10.30	11.20	14.50	16.48	9.73
	T 0.02	15.90	13.63	12.51	13.85	16.52	11.55	16.95	13.65	19.70	10.07	15.45	9.90
	C 0.02	8.55	14.13	13.12	14.13	10.07	12.63	10.07	12.02	13.95	12.60	12.90	19.50
	S 0.02+C0.02	15.27	13.27	11.24	13.05	16.33	12.38	16.33	11.98	19.80	13.80	23.42	18.50
	S 0.02+C0.01	12.23	17.17	14.75	16.95	13.05	12.73	13.03	17.10	16.30	15.75	13.48	16.48
	T 0.02+C0.02	14.27	16.30	14.75	15.30	10.18	13.50	10.18	16.35	9.90	13.75	13.55	15.95
	T 0.02+C0.01	11.53	19.05	15.24	19.20	14.18	13.20	14.18	14.85	13.23	14.43	12.13	14.85
	S 0.02+T 0.02	16.00	12.85	11.22	13.43	11.77	14.30	11.77	15.27	11.68	13.63	14.75	10.73
	S 0.01+T 0.02	9.25	12.50	10.42	12.20	11.90	16.15	8.90	14.52	11.93	11.90	15.10	13.40
	S 0.01+T 0.01+ C 0.01	9.63	16.02	9.52	9.70	9.10	17.80	11.10	14.45	14.30	17.20	15.50	8.77
	S 0.01+T 0.01+ C 0.02	15.80	11.85	9.87	15.80	16.65	17.67	16.65	14.65	15.18	15.48	17.75	7.05
	S 0.02+T 0.01+ C 0.01	15.30	17.88	9.63	12.55	16.05	14.23	16.05	13.30	12.27	13.20	12.77	11.30
	S 0.02+T 0.02+ C 0.01	12.18	11.52	10.11	17.15	13.45	14.10	13.45	15.88	16.48	18.05	15.18	6.95
Direct application of antioxidants in frying oil	S 0.01	18.25	16.45	15.12	15.50	15.08	10.38	19.08	14.13	15.65	12.57	14.52	19.05
	T 0.01	15.73	18.27	14.42	18.77	16.95	11.30	16.95	16.92	11.77	13.88	12.65	10.27
	C 0.02	16.00	12.68	10.32	11.95	19.90	19.30	16.90	16.60	18.70	15.35	11.38	17.83
	S 0.02+C0.02	14.03	13.75	12.10	13.52	15.20	14.95	15.20	15.00	15.85	17.60	12.88	17.83
	S 0.01+C0.01	15.55	12.90	10.52	12.90	16.58	15.25	16.56	9.95	13.80	10.45	16.77	16.05
	T 0.02+C0.01	10.18	11.13	10.89	11.13	11.57	13.48	11.57	13.68	11.07	11.73	12.73	16.27
	T 0.01+C0.02	14.63	13.77	12.56	13.25	15.52	12.60	15.52	15.23	16.00	14.20	14.90	16.33
	S 0.02+T 0.02	15.73	10.60	16.42	11.10	13.20	12.52	13.20	10.93	13.95	12.65	12.85	13.65
	S 0.01+T 0.02	15.90	12.63	12.45	12.82	14.88	13.75	14.88	14.48	10.05	15.73	13.40	14.63
	S 0.02+T 0.02+ C 0.02	14.13	12.73	10.44	12.93	13.38	15.10	13.38	11.52	12.52	14.30	11.63	14.30
	S 0.02+T 0.01+ C 0.01	15.55	11.75	11.42	13.45	12.65	17.45	12.65	15.52	12.98	11.88	14.10	15.52
	S 0.02+T 0.01+ C 0.02	15.27	16.23	9.42	12.25	11.27	16.67	9.27	11.57	11.77	14.60	12.98	18.33
	S 0.01+T 0.02+ C 0.02	12.23	15.43	10.11	16.00	13.05	16.50	13.05	15.23	15.70	15.52	15.23	14.80
	Control	14.80	11.85	12.35	12.25	15.45	12.00	15.45	12.93	12.27	13.20	8.55	7.52
	Assym sig.	0.000	0.006	0.001	0.0012	0.000	0.010	0.000	0.003	0.002	0.000	0.000	0.000

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

4.3.3.1.c. Taste

Chips prepared after adding 0.02% curry leaf powder and packed in laminated pouches scored maximum for taste from 15 days (18.57) to 60 days (19.38) and at 90 days (18.05). Chips from slices presoaked in 0.02% tocopherol acetate scored highest rank (16.67) during 75 days, which was the second best during 15,30 and 90 days of storage (Table 29.).When packed in LDPE pouch, chips from slices presoaked in 0.02% tocopherol acetate recorded maximum score during 15 (16.52) and 60 (17.58) days. When tocopherol was added to oil directly at 0.01% concentration, it scored highest (18.40) rank during 30 days. At the end of storage, direct application of 0.02% curry leaf had maximum score (20.52) for taste. Untreated chips recorded least score (10.32 and7.45) and (9.63 and 6.70) during 75 and 90 days when packed in laminated and LDPE pouches respectively.

In general chips prepared after direct addition of 0.02 % curry leaf powder in oil, had highest score for appearance (18.18),for flavour(19.30) and taste(18.05) at the end of storage in laminated pouch. When stored in LDPE pouch, these chips had maximum score for taste (20.52) and appearance (16.60).These results indicate that the treatment, which was having high physical and chemical quality parameters had high acceptability among judging panel also.

4.4.COST OF PRODUCTION

Cost of production of 1 Kg banana chips was computed (Appendix II). Cost of production of chips considering the labour and overhead cost involved is Rs.472.41. The cost becomes Rs.473.29, when curry leaf is added as an antioxidant and the chips packed in laminated pouch. The increase in cost of production is marginal and hence the selected antioxidant is economic also.

Table.29. Taste of treated chips during storage

		Days after storage						Days after storage					
	Treatments	15	30	45	60	75	90	15	30	45	60	75	90
		Laminated pouch						LDPE pouch					
Presoaking of slices in antioxidants	S 0.01	16.20	16.38	16.05	6.03	16.50	16.38	15.77	13.35	19.63	15.43	14.48	10.68
	T 0.02	17.38	18.52	16.50	7.32	16.67	17.77	16.52	12.68	11.82	17.58	16.38	14.40
	C 0.02	11.35	10.38	10.65	12.35	15.40	12.50	12.85	16.52	18.08	12.50	11.00	17.75
	S 0.02+C0.02	11.30	11.70	15.48	13.73	15.40	12.20	14.57	10.30	9.48	14.82	10.98	13.45
	S 0.02+C0.01	8.50	10.75	11.98	17.27	12.23	8.18	10.20	17.95	10.18	6.80	11.38	12.65
	T 0.02+C0.02	14.23	14.88	15.68	11.10	15.98	8.42	16.38	17.15	5.47	15.32	13.27	13.98
	T 0.02+C0.01	15.40	16.40	10.52	16.20	9.43	10.23	14.93	19.45	7.38	14.63	15.40	14.27
	S 0.02+T 0.02	11.30	15.63	14.85	14.38	14.38	14.82	10.50	16.90	21.15	15.38	15.25	13.15
	S 0.01+T 0.02	8.02	14.02	16.73	11.45	16.45	15.15	11.50	9.63	18.83	15.82	13.75	13.55
	S 0.01+T 0.01+ C 0.01	14.82	9.50	10.65	11.45	10.75	15.70	14.50	16.77	16.80	12.63	15.63	10.60
	S 0.01+T 0.01+ C 0.02	15.40	15.55	9.85	17.02	13.10	8.48	14.93	17.10	15.00	12.55	18.13	13.23
	S 0.02+T 0.01+ C 0.01	14.38	13.52	16.73	16.50	14.86	8.25	13.75	10.07	19.23	12.93	13.00	14.52
	S 0.02+T 0.02+ C 0.01	8.52	14.90	15.48	14.02	10.52	15.52	8.40	16.33	13.35	14.95	15.10	11.93
Direct application of antioxidants	S 0.01	17.13	18.05	16.42	11.27	16.52	17.70	16.38	18.00	20.58	15.45	13.57	14.68
	T 0.01	15.93	17.00	14.25	11.20	14.48	16.05	15.15	18.40	14.70	15.27	14.20	13.05
	C 0.02	18.57	18.88	18.68	19.38	11.90	18.05	16.15	12.10	15.32	15.50	10.95	20.52
	S 0.02+C0.02	14.38	13.65	14.85	16.23	14.77	15.70	14.63	13.60	11.15	13.55	14.13	16.90
	S 0.01+C0.01	14.82	14.27	16.73	15.95	16.45	11.05	15.20	14.18	12.18	16.27	15.25	12.77
	T 0.02+C0.01	12.77	11.93	17.68	17.25	10.75	10.23	12.88	10.02	13.13	9.65	14.18	14.07
	T 0.01+C0.02	14.90	16.42	18.05	17.45	13.15	10.20	14.55	10.57	12.80	14.15	15.50	12.25
	S 0.02+T 0.02	14.38	15.50	14.68	17.45	12.05	10.15	15.35	6.60	11.38	15.68	12.80	14.82
	S 0.01+T 0.02	14.82	15.23	10.65	16.75	15.65	12.45	13.40	17.25	15.55	13.77	12.63	11.30
	S 0.02+T 0.02+ C 0.02	17.38	10.55	13.05	17.02	15.40	8.48	14.98	12.32	12.70	12.38	12.25	14.93
	S 0.02+T 0.01+ C 0.01	15.57	11.82	15.68	16.50	12.23	17.77	14.38	12.85	11.52	11.20	15.30	13.95
	S 0.02+T 0.01+ C 0.02	11.35	13.65	10.82	14.02	15.40	13.90	11.43	12.30	17.23	13.38	14.38	13.38
	S 0.01+T 0.02+ C 0.02	14.38	12.15	14.68	16.83	12.23	12.52	12.23	13.57	6.13	15.35	16.52	14.52
	Control	17.38	11.77	11.98	16.52	14.32	10.32	7.45	12.02	17.27	15.07	9.63	6.70
	Assym sig.	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.001	0.000	0.003	0.012

S-Sodium ascorbate T-Tocopherol acetate C-Curry leaf powder

Summary

5. SUMMARY

The present investigation entitled "Effect of antioxidants and packaging in controlling rancidity of banana chips during storage" was carried out to evaluate and compare the effect of antioxidants and packaging materials on the rancidity problem of banana chips, to delay the onset of oxidation during storage and to enhance shelf life of packed product. The experiment was conducted in the Department of Processing Technology, College of Agriculture, Vellayani during the period 2009-2011. The investigation was carried out as three different experiments.

1. Standardization of frying parameters for banana chips preparation.
2. Effect of antioxidants on quality of banana chips.
3. Storage stability and acceptability of antioxidant treated banana chips.

The major findings are summarized as follows

Chips were prepared from Nendran banana using unrefined coconut oil by varying different frying parameters like temperature of frying oil, oil-slice ratio, salt and turmeric concentration. Appearance, colour, flavor, texture, taste and overall acceptability of the 54 treatment combinations of chips were evaluated organolepticaly. The treatments which recorded lowest ranks for all the parameters contained lower concentration of turmeric (0.10 %), higher and lower frying temperatures. Highest rank score for flavour (9.93), taste (9.41) and overall acceptability (9.76) were recorded by $H_2M_1S_3T_2$.This combination also showed second best rank for appearance (9.71) and texture (9.88). The weighted average ranks of the 54 chips combination were calculated based on the importance of characters and chips combinations having higher calculated weighted average rank and mean ranks for overall acceptability were selected for the next experiment. Fourteen superior treatments from preliminary trial were repeated and organoleptically scored. Based on the mean ranks of quality parameters, the most acceptable treatment was selected and different parameters for banana chips preparation were standardized. Frying banana slices at smoke point of 165 ^{o} C with 2;1 oil-slice ratio and adding 0.7 % salt and 0.15 % turmeric gave banana chips of higher acceptability.

The most effective method and form of curry leaf to prevent rancidity of unrefined coconut oil were determined. Curry leaf was added @ 0.01% on w/w basis to unrefined coconut oil at smoke point of 165^{0}C in four different methods. Application of oven dried(60^{0} C for 6 hours) and ground curry leaves to unrefined coconut oil was identified as the best method of curry leaf application to prevent rancidity and this method was selected for the further experiments.

Three different antioxidants viz., sodium ascorbate, tocopherol acetate and curry leaf powder were incorporated in two concentrations (0.01 and 0.02 %) to banana chips in two different methods. Banana chips were prepared from slices either after presoaking in antioxidant solution for 30 minutes and surface drying for 30 minutes; or after adding antioxidants directly to the frying oil. Banana chips were prepared after incorporating antioxidants and were subjected to organoleptic analysis. The top ranking 26 treatments were selected organoleptically, 13 from each method and were repeated along with control for further study. Physical parameters like yield, oil uptake, moisture, integrity of chips prepared after adding antioxidants are considered together, all the groups had similar shrinkage and integrity. Chips with lowest oil uptake and moisture can be considered to have good quality. Group I antioxidants had least oil uptake(30.98%) and lowest moisture content(0.25%). Among group I antioxidants, 0.02% curry leaf powder with least oil uptake (30.25) and highest integrity (94.90) can be considered as the antioxidant with good physical parameters.

When physical parameters of chips prepared from slices soaked in antioxidants are considered, all the groups had similar yield and shrinkage ratio. However untreated chips had highest yield (70%) and shrinkage ratio(23.15)

Untreated chips had highest oil uptake (40.34%) and moisture (0.93 %), compared to treated chips , resulting in increased yield.

Presoaking slices in group I antioxidants resulted in chips with least oil uptake(34.17%) and moisture content (0.52 %) and hence can be considered advantageous. Antioxidant within group I had similar effect on all physical parameters.

Untreated chips had a higher and acceptable colour (yellowness index) compared to treated chips .Chips produced from slices presoaked in group I antioxidants had lowest yellowness index (112.47) ,giving a faded appearance. Group II treatments resulted in chips of highest yellowness index (116.11) giving a very dark yellow colour.

Crispness and toughness of all treated chips prepared from slices presoaked in antioxidants was similar to that of untreated chips. Regarding hardness, untreated chips had least hardness(5.64 N) which was on par with chips prepared from slices presoaked in group I antioxidants.(6.01 N)

When chips were prepared after adding antioxidants in oil were compared on textural quality, all of them were similar in crispness, hardness and toughness. It indicates that textural quality is not affected by adding antioxidants directly in oil.

If chips are prepared from slices presoaked in antioxidants, their crispness and toughness are not affected. Hardness is affected when group II and III antioxidants are used, whereas chips prepared after presoaking in group I antioxidants is similar in hardness as that of untreated chips. Though treated chips did not make any difference in hardness and toughness, crispness is improved by adding antioxidants. Crispness was also retained during storage.

The antioxidants selected in the two methods of application were different. But some antioxidants were common in both the methods. Comparing the groups, group I antioxidants had lower moisture and oil uptake. So by comparing the efficiency of two such treatments in group I category in both the methods regarding important physical quality parameters like moisture, oil uptake and integrity, it is seen that the chips prepared after adding antioxidants in the oil had lower moisture content, less oil uptake and better integrity compared to the chips prepared from presoaked slices.

None of the treatments showed a superior performance in chemical quality when it is applied as a presoaking method. 0.01% sodium ascorbate was better compared to other treatments. But when, applied directly in oil, 0.02% curry leaf powder showed superior performance by recording lower free fatty acid value, peroxide value and a higher iodine value. Chips treated with 0.02% curry leaf had highest integrity also. When the efficiency of two methods was compared, the chemical parameters like free fatty acid content and peroxide value were lower in direct application, indicating its efficiency. When the combination of antioxidants was used, there was no significant reduction in the free fatty acid and peroxide value of treated chips; hence there is no advantage in combining the antioxidants.

Among the two method of application of antioxidants studied, presoaking method gives inferior results compared to the direct application method in terms of oil uptake, residual moisture, integrity and chemical quality. Presoaking the slices for 30 minutes in the antioxidant solution and surface drying for 30 minutes is time consuming and the results are not worth considering the extra time and labour consumed.

0.02 % curry leaf which had better chemical quality among the directly added antioxidants resulted in higher organoleptic quality for texture(19), taste(18.57) and overall acceptability(17.52), hence can be recommended for improving the quality of banana chips.

Moisture content of chips stored in two packages gradually increased through out storage and the increase is comparatively less in laminated pouches. The increase in moisture content of untreated chips was more compared to treated ones at the end of storage.

When the chemical quality of treated chips was evaluated during storage, their performance was always superior to the untreated ones. 0.02 % curry leaf powder gave better results in terms of low free fatty acid value, peroxide and high iodine values through out storage in the direct application method. Since this natural product gives superior results than the two commercially available antioxidants, it can be considered as the best antioxidant for controlling rancidity of banana chips during storage also. 0.01 % sodium ascorbate gave better result in the presoaking method. But the performance was poor in direct application method.

The antioxidants applied individually gave superior results for the quality parameters followed by a combination of two antioxidants .Direct application of antioxidants to the frying oil produced better results in terms of physical, chemical and organoleptic quality. Direct addition of 0.02 % curry leaf powder was considered as the best antioxidant for controlling rancidity of banana chips and it was having shelf stability also.

Laminated pouch was found better when compared to LDPE pouch in terms of physical and chemical quality.

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Abstract

ABSTRACT

The research project entitled "Effect of antioxidants and packaging in controlling rancidity of banana chips during storage" was conducted at Department of Processing Technology, College of Agriculture, Vellayani, with the objective to evaluate and compare the effect of antioxidants and packaging materials on the rancidity problem of banana chips, to delay the onset of oxidation during storage and to enhance shelf life of packed product. The whole experiment was divided into three parts viz., Standardization of frying parameters for banana chips preparation, Effect of antioxidants on quality of banana chips and Storage stability and acceptability of antioxidant treated banana chips.

Frying two mm thick banana slices in unrefined coconut oil at 165^{o}C, with an oil: slice ratio of 2:1 by adding 0.7 % salt and 0.15 % turmeric resulted in banana chips of higher acceptability.

Two concentrations (0.01 and 0.02 %) of three different antioxidants viz., sodium ascorbate, tocopherol acetate and curry leaf powder were incorporated into banana chips in two different methods. Banana slices were either presoaked in antioxidants for 30 minutes or added directly to the frying oil. Addition of curry leaf in oven dried (at 60^{0} C for 6 hours) and ground form was identified as the best method and form of curry leaf application for delaying the onset of rancidity. Experiment was laid out in CRD with two replications. The prepared chips were packed in trilayered laminated pouch (LDPE/metalized polyester /LDPE) and LDPE pouch for evaluation of shelf stability.

Physical parameters like oil uptake and moisture content were lower for antioxidant treated chips, compared to untreated chips, indicating its superiority. Textural parameters like crispness and toughness were not affected by incorporating antioxidants in chips.

Addition of group I antioxidants produced chips with lower moisture and oil uptake. These chips recorded a lower free fatty acid value and peroxide value compared to chips produced with group II and III indicating the inefficiency in combining the antioxidants.

Chips prepared after adding antioxidants in oil had better physical and chemical quality parameters compared to the chips prepared from presoaked slices.

Chips prepared after direct application of 0.02% curry leaf powder in oil showed superior physical and chemical parameters. These chips recorded higher organoleptic scores for texture, taste and overall acceptability. Their performance was better through out storage, hence can be considered as the best antioxidant tried for controlling rancidity of banana chips during storage also.

There was an increase in moisture content, free fatty acid value and peroxide value and decrease in iodine value of chips during storage. Quality degradation was slower in laminated pouches compared to chips stored in LDPE.

Banana chips produced after direct addition of 0.02 % curry leaf powder in oil had better physical, chemical and sensory characters, which are retained in storage when packed in laminated pouches.

Appendices

APPENDIX I

Kerala Agriculture University
College of Agriculture
Department of Processing Technology

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BANANA CHIPS

Name of student: Adrika B.V. (2009-12-101)

Title Of Thesis: Effect Of Antioxidants And Packaging In Controlling Rancidity Of Banana Chips During Storage

Criteria	SAMPLES				
	1	**2**	**3**	**4**	**5**
Appearance					
Colour					
Flavour					
Texture					
Taste					
Any Other Remarks					

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

Date :

Name :
Signature:

APPENDIX II

COST OF PRODUCTION

Items	Market price	Cost of production (1 Kg chips)			
		Without antioxidant		With antioxidant	
		Quantity	Cost(Rs.)	Quantity	Cost (Rs.)
Raw banana	Rs.26/kg	3 Kg	78.00	3 Kg	78.00
Coconut oil	Rs.92/kg	4 Kg	368.00	4 Kg	368.00
Turmeric powder	Rs.32/50 g	3.00 g	5.00	3.00 g	5.00
Salt	Rs.15 /1 kg	14g	0.21	14g	0.21
Labour			10		10
Overhead expense			10		10
Curry leaf powder	Rs.40 /Kg		-	0.04	0.08
Laminated pouch	Rs.1/ pouch		-	2	2
Polythene pouches	0.30/ pouch	4	1.20		
Total			**472.41**		**473.29**