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Research Article

Chemical Composition of Banana (*Musa* spp.) Chips as Influenced by Osmotic Treatments, Drying Methods and Storage Period

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ABSTRACT

Bananas (*Musa* spp.) belong to the Musaceae family of the order Zingiberales and are giant perennial herbs which originated from intra and interspecific crosses of *Musa accuminata* and *Musa balbisiana*. Banana chips production is an excellent alternative food supply and minimizes postharvest losses and retains the nutritive value of fresh bananas and stable markets. This study was conducted to determine the effect of osmotic treatment, drying method and storage period on chemical composition of banana chips. Banana chips were prepared by open sun and oven drying methods after treating the fruit in 30° Brix and 60° Brix sugar syrup for 18 hours. Completely randomized design was used with three factor arrangement (3 × 2 × 4) and analyzed by SAS 9.1. Chips were stored at room for 90 days and analyzed for chemical composition after every 30th day's interval. A significant interaction effect of Pre-treatments, drying methods and storage period were observed during storage. The crude protein, crude fat, crude fiber, ash and pH decreased with advancement of storage period, whereas titratable acidity, reducing sugar, total sugar, non-reducing sugar and total soluble solid significantly increased with increase in storage period.

Keywords: Banana chips; Banana drying; Osmotic treatments; Storage studies of chips

INTRODUCTION

Bananas (*Musa* spp.) are giant perennial herbs which originated from intra and interspecific crosses of *Musa accuminata* and *Musa balbisiana*. The fruit belongs to the Musaceae family of the order Zingiberales and is one of the most important fruit crops of the world. It was originated in south pacific and south East Asia [1]. World banana production is concentrated in Africa, Asia, the Caribbean and Latin America because of suitable growing conditions. Among the various continents, Asia has the lion share of 60% of the global banana production. Approximately one third of the bananas produced globally are grown in Sub-saharan Africa, where the crop provides more than 25% of food energy requirements for more than 100 million people. In 2017, banana was the world's most productive fruit crop with an annual production of 113,918,763 metric tons [2]. Banana fruit is a rather demanded product as it is delicious and nutritious. The production, consumption and trade of banana is in high volumes in the world, it is being exported from tropical and subtropical regions to the developed countries and it can easily find market for sale in these countries [3].

Banana is popular globally not only for its nutritional value, but also for its economic importance especially to small and marginal farmers in developing countries. It is grown in over 130 countries across the world in an area of 10.1 million ha producing 121.85 million tons [4]. Dessert banana and plantain (*Musa* spp.) are the fourth most important staple food crops in the world next to rice, wheat and maize [5]. It is in particular a commercially important crop in the global trade, both by volume and value, as a leading fruit [6]. For many African, Asian and Latin American countries, banana is the most important crops for foreign exchange earnings as well.

Ethiopia lies entirely in the tropics and has great potential for banana production due to suitable agro climatic conditions. Cavendish banana is the major fruit crop that is most widely grown and consumed in the country. In the south and southwestern parts of the country, it has great socioeconomic

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importance as it contributes to food security, income generation and job creations. In Ethiopia banana contributes around 47.83% for producers' own consumption, 49.19% for income generation, 0.47 for animal feed and 2.52% for other purposes [7]. It covers about 59.64% (53,956.16 hectares) of the total fruit area, about 68.00% (478,251.04 tons) of the total fruits produced and about 38.30% (2,574,035) of the total fruit producing farmers in Ethiopia. On the other hand about 68.72% (37,076.83 tons) of land covered under banana, about 77.52% (370,784.17 tons) of the banana production and 22.38% (1,504,207) of the banana producers in Ethiopia are found in the Southern Nations Nationalities and Peoples Regional State (SNNPRS) (5). Gamo Gofa, Bench Maji and Sheka zones are among the major banana producing zones of the SNNPRS, of which Gamo Gofa zone alone covers over 70% of the total banana marketed across the major outlets in Ethiopia [8].

Banana crop is an important source of income particularly in locations where small holders are producing. But, banana faces so many problems from harvesting until reaching to the consumer. Postharvest loss of perishable commodities such as banana in the world reached 50% and this loss in Ethiopia is reported to be 30% every year. Annually huge economic losses are being faced. These huge losses could be reduced significantly by developing value added products like banana flour, banana chips, banana sauce, banana jam etc. There are numbers of techniques to preserve banana fruit which also include drying. The drying of the fruit can be performed by open sun drying, mechanical dehydration, freeze drying and osmotic treatment. But, in a developing country like Ethiopia where there are limited resource and infrastructures, the options for high investment infrastructures like freeze drying are not possible. Low cost technologies and mechanisms must be selected in order to increases the quality of product and to prolong the shelf-life of banana fruit. It is therefore imperative to develop suitable technology for preservation and processing of such a nutritious fruit. Chips are among the most popular snacks in many fast food outlets [9] and are the most popular product [10]. The production of banana chips is widespread activity in many banana growing countries. With the above background in mind the present research was conducted to standardize technologies for drying banana chips in a manner that the technology is simple and affordable for common farmers and entrepreneurs and the product maintains the required quality parameters.

The main objective of this study is to determine the effect of osmotic treatment, drying method and storage period on chemical composition, sensory and nutritional properties of banana chips.

MATERIALS AND METHODS

Experimental materials

The Cavendish banana with dwarf height (*Musa* spp.) commonly grown in Ethiopia was used for this study. The fresh fruit harvested at the optimum maturity stage was obtained from Arba Minch zuria werda, Gamo zone from omotic farm. The fruit was stored at room temperature until it was required for preparation. Individual fingers of banana fruit were separated from the hands of bunch. The sugar in crystal and purified form was bought from supermarket.

Experimental design and treatment

The experiment was arranged out in a Completely Randomized Design (CRD) with three replications in 3*2*4 complex factorial design. The experimental treatment consisted of three level of osmotic treatment namely 0° Brix, 30° Brix and 60° Brix sugar solution, two types of drying method namely oven and open sun drying and four levels of storage periods namely 0, 30, 60 and 90 days. The stored dried banana chips were evaluated at every thirty days' interval for total period of ninety days. Randomization of the treatments was done by lottery method [11].

Sample preparation

Sugar nearly 30% and 60% was dissolved in two separate bucket of water maintaining sample to solution ratio of 1:3 (w/v). TSS of solution was observed using hand refractometer. The TSS was adjusted to 30° Brix and 60° Brix in the two solutions by adhering Pearson's formula and confirmed using hand refractometer. The banana slices were divided into three lots. Out of three lots, two lots were taken for osmotic treatments. One of two lots for 30° Brix treatment and the other for 60° Brix treatment. The third lot served as a control and was not given any treatment. Osmotic treatments of 30° Brix and 60° Brix were given by soaking the slices in the sugar syrup for 18 hours as prescribed by ensuring full coverage of the slices [12].

All the three lots of the slices (control, soaked in 30° Brix and 60° Brix syrup) were further divided into two sub lots. One of the sub lots from each treatment was dried in oven at 50-55°C and another sub lots was dried under open sun. Fruit slices were turned upside down at appropriate time intervals for maintaining uniformity of drying. All the sub lots were dried to a level that the moisture content ranged from 15-25%. Each of the dried product lots was packed in transparent PET jars with air tight lids. Each jar was labeled properly to describe nature of treatment. The product was stored at room temperature for a period of 90 days and the product was analyzed for various parameters after every 30 days [13].

Chemical analyses of banana chips

The proximate composition (*i.e.*, ash, crude fiber, crude fat, crude protein and moisture) of banana chips was determined using methods Association of Official Analytical Chemists (2) methods, while carbohydrate content was calculated by difference as follows:

Carbohydrate (%)=100-(% Moisture+% Fat+% Ash+% fibre+% protein)

pH determination

The pH of the sample was measured with pH meter. Five gram of banana chips and dissolves with 50 mL of distilled water and placed into 100 mL beakers for pH determination. Prior to pH measurement, the instrument was calibrated with pH 4, 7 and

10 buffers solution then the standardized electrode tip was immersed in the sample solution and the sample was kept until it reenter constant pH value, then the reading was recorded from pH meter (Model: JENWAY 3310) at ambient temperature [14].

Titratable acidity determination

The titratable acidity expressed as percent of malic acid and determined by titrating the decanted homogenate used for pH measurement against 0.1 NaOH to pH 8.0 using phenolphthalein as an indicator. The amount of malic acid (%) was calculated using the malic acid equivalent factor 0.067.

Malic acid (%)=(mL of NaOH) × (0.1 NaOH) × (0.067)/(weight of sample) × 100

The sugar content (*i.e.,* total sugar content and reducing sugar) of banana chips was determined using methods association of official analytical chemists (2) methods, while non-reducing sugar content was calculated by difference as follows:

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

RESULTS

Standard AOAC method was used to determine chemical composition using standard analytical methods. The collected data was subjected to Analysis of Variance (ANOVA) by using SAS software version 9.1 and mean separation was done using Duncan's multiple range tests at 5% level of significance (Tables 1 and 2).

Table 1: Interaction effect of osmotic treatment, drying method and storage period on proximate composition of banana chips.

Treatments			**Chemical compositions**						
Osmotic treatment	**Drying method**	**Storage (days)**	**CP (%)**	**CF (%)**	**Ash (%)**	**MC (%)**	**CFB (%)**	**CHO (%)**	**DM (%)**
Untreated	Oven	Initial	2.35 ± 0.006^{f}	0.43 ± 0.01^{e}	5.94 ± 0.25^{a}	17.97 ± 0.006^{fe}	29.47 ± 0.02^{a}	47.01 ± 0.07^{p}	82.04 ± 0.005^{lm}
	Oven	30	3.51 ± 0.02^{a}	0.41 ± 0.005^{f}	5.77 ± 0.01^{b}	17.98 ± 0.00^{e}	7.47 ± 0.00^{j}	68.21 ± 0.03^{i}	82.02 ± 0.00^{m}
	Oven	60	2.96 ±0.055	0.07 ± 0.01^{k}	3.10 ± 0.01^{j}	17.98 ± 0.015^{e}	5.83 ± 0.04^{m}	70.73± 0.07^{e}	82.02± 0.015^{m}
	Oven	90	1.64 ± 0.01^{j}	0.03 ± 0.005^{n}	2.89 ± 0.01^{k}	18.11± 0.09^{d}	4.82 ± 0.00^{o}	71.53± 0.12^{cb}	81.89± 0.09^{n}
	Sun	Initial	2.99 ± 0.00^{b}	0.76 ± 0.00^{a}	5.93 ± 0.005^{a}	17.82 ± 0.01^{h}	23.80± 0.02^{e}	52.99± 0.03^{m}	82.18 ± 0.01^{j}
	Sun	30	2.35 ± 0.006^{f}	0.50 ± 0.005^{d}	4.45 ± 0.01^{ef}	17.92 ± 0.006^{fg}	9.64 ± 0.006^{g}	67.79 ± 0.005^{j}	82.08 ± 0.006^{lk}
	Sun	60	2.09 ± 0.01^{hg}	0.31 ± 0.005^{g}	3.25 ± 0.03^{i}	18.09 ± 0.03	7.69 ± 0.15^{i}	69.29 ±0.15	81.90 ± 0.03
	Sun	90	1.89 ± 0.09^{i}	0.05 ± 0.01l	2.53 ± 0.02l	19.38 ± 0.005^{a}	5.72 ± 0.27^{m}	70.07 ± 0.19^{f}	80.62 ± 0.006^{q}
Treated with 30°Brix sugar conc.	Oven	Initial	2.90 ± 0.09^{c}	0.55 ± 0.01^{c}	4.66 ± 0.02c	16.85 ± 0.005^{o}	17.97 ± 0.51^{f}	59.21 ± 0.57^{k}	83.15 ± 0.005^{c}
	Oven	30	2.45 ± 0.006^{e}	0.39 ±0.005	4.56 ± 0.03^{d}	16.97 ± 0.025	4.24 ± 0.005	71.44 ±0.03	83.02 ± 0.03
	Oven	60	2.30 ± 0.006^{f}	0.05 ± 0.005^{ml}	4.29 ± 0.03^{h}	17.19 ± 0.125^{l}	4.26 ± 0.25^{p}	71.36 ± 0.05^{c}	82.80 ± 0.125^{f}
	Oven	90	1.21 ± 0.005l	0.01 ± 0.005^{o}	3.05 ± 0.01^{j}	17.90 ±0.02	4.96 ± 0.015^{o}	71.69 ± 0.41^{b}	82.10 ± 0.02
	Sun	Initial	2.54 ± 0.03^{d}	0.39 ± 0.005^{f}	4.51 ± 0.01	16.02 ± 0.01	24.63 ± 0.025^{d}	54.19 ± 0.05^{l}	83.98 ± 0.01^{a}
	Sun	30	2.09 ± 0.03^{hg}	0.19 ± 0.005^{j}	4.50 ±0.02	17.44 ± 0.01^{k}	7.97 ± 0.00^{h}	69.26 ± 0.05^{h}	82.56 ± 0.01^{g}
	Sun	60	2.54 ± 0.01^{d}	0.03 ± 0.01^{n}	2.54 ± 0.01^{l}	17.44 ± 0.005^{k}	6.98 ±0.015	69.91 ± 0.03^{f}	82.56 ± 0.006^{g}

	Sun	90	1.08 ± 0.025^{m}	0.01 ± 0.00^{o}	2.46 ± 0.08^{ml}	18.99 ± 0.005^{b}	4.04 ± 0.06^{qr}	71.48 ± 0.01^{cb}	81.00 ± 0.005^{p}
Treated with 60°Brix sugar conc.	Oven	Initial	1.55 ± 0.06^{k}	0.52 ± 0.005^{d}	4.40 ± 0.06^{gf}	15.97 ± 0.005^{q}	24.95 ± 0.04	53.76 ± 0.04^{n}	84.03 ± 0.005^{a}
	Oven	30	2.91 ± 0.0057^{c}	0.29 ± 0.00^{h}	4.31 ± 0.02^{gh}	16.79 ± 0.00^{p}	7.13 ± 0.00^{k}	68.22 ± 0.02^{i}	83.21 ± 0.00^{b}
	Oven	60	1.08 ± 0.03^{m}	0.21 ± 0.01^{i}	2.43 ± 0.03^{m}	16.98 ± 0.02^{n}	$6.29 \pm 0.06l$	67.79 ± 0.058^{j}	83.02 ± 0.020^{d}
	Oven	90	1.89 ± 0.005^{j}	0.01 ± 0.00^{o}	1.85 ± 0.07^{on}	17.04 ± 0.025^{m}	2.98 ± 0.015^{s}	72.33 ± 0.030^{a}	82.96 ± 0.025^{e}
	Sun	Initial	2.12 ± 0.005^{hg}	0.67 ± 0.02^{b}	4.33 ± 0.06^{gh}	16.74 ± 0.005^{p}	25.71 ± 0.005^{b}	50.47 ± 0.12^{o}	83.26 ± 0.005^{b}
	Sun	30	2.15 ± 0.05^{g}	0.29 ± 0.005^{h}	1.90 ± 0.05^{n}	17.55 ± 0.00^{j}	5.22 ± 0.10^{n}	72.39 ± 0.10^{a}	82.45 ± 0.00^{h}
	Sun	60	2.06 ± 0.005^{h}	0.037 ± 0.005^{mn}	1.80 ± 0.10^{o}	17.74 ± 0.005^{i}	4.83 ± 0.150^{o}	71.01 ± 0.25	82.26 ± 0.005^{i}
	Sun	90	1.06 ± 0.04	0.01 ± 0.00^{o}	1.64 ± 0.01^{p}	18.88 ± 0.04^{c}	3.98 ± 0.01^{r}	$69.56 \pm 0.26g$	81.12 ± 0.04^{o}
CV (%)			1.96	2.89	1.48	0.18	1.17	0.21	0.04

NB: Means followed by the same letter within a column are not significantly different from each other at 5% level of significance. CV: Coefficient of Variation; MC=Moisture Content; CFB: Crude Fiber; CP: Crude Protein; CF: Crude Fat; CHO=Total Carbohydrate and DM: Dry Matter content

Table 2: Interaction effect of osmotic treatment, drying method and storage period on chemical composition of banana chips.

Treatments			Chemical Compositions					
Osmotic treatment	**Drying method**	**Storage (days)**	**pH**	**TA (%)**	**TSS (0B)**	**TS (%)**	**RS (%)**	**NRS (%)**
Untreated	Oven	Initial	5.46 ± 0.39^{c}	0.55 ± 0.02^{j}	10.85 ± 0.01^{v}	16.01 ± 0.09^{q}	11.73 ± 0.10^{k}	4.28 ± 0.005^{p}
	Oven	30	5.34 ± 0.01^{dfce}	0.57 ± 0.005^{n}	22.25 ± 0.10^{p}	18.94 ± 0.03^{l}	13.53 ± 0.02^{j}	5.40 ± 0.005^{l}
	Oven	60	5.32 ± 0.07^{gdfce}	0.60 ± 0.006^{i}	25.03 ± 0.01^{n}	21.29 ± 0.01^{h}	15.86 ± 0.01^{g}	5.43 ± 0.005^{lk}
	Oven	90	5.19 ± 0.01^{gfih}	0.88 ± 0.01^{a}	33.94 ± 0.02^{g}	23.14 ± 0.06^{f}	16.19 ± 0.065^{f}	6.94 ± 0.01^{e}
	Sun	Initial	5.37 ± 0.01^{dfce}	0.47 ± 0.01^{l}	10.39 ± 0.04^{w}	10.65 ± 0.105^{x}	6.68 ± 0.095^{t}	3.37 ± 0.01^{s}
	Sun	30	5.29 ± 0.01^{ih}	0.34 ± 0.01^{p}	18.06 ± 0.01^{r}	16.69 ± 0.04^{o}	11.78 ± 0.034^{k}	4.91 ± 0.01^{o}
	Sun	60	5.21 ± 0.0^{gdfieh}	$0.71 \pm 0.01f$	24.75 ± 0.025^{o}	18.69 ± 0.05^{m}	13.55 ± 0.035^{j}	5.14 ± 0.025^{n}
	Sun	90	5.02 ± 0.01^{i}	0.82 ± 0.00^{d}	32.99 ± 0.06^{i}	19.41 ± 0.125^{k}	14.27 ± 0.025^{i}	5.15 ± 0.15^{n}
Treated with 30°Brix sugar conc.	Oven	Initial	5.27 ± 0.01	0.35 ± 0.01^{op}	15.02 ± 0.49^{u}	12.49 ± 0.12^{t}	9.12 ± 0.11^{n}	3.98 ± 0.01^{q}
	Oven	30	5.26 ± 0.01^{gfih}	0.34 ± 0.01^{o}	30.53 ± 0.028^{k}	12.76 ± 0.05^{s}	7.29 ± 0.04^{r}	5.47 ± 0.01^{k}
	Oven	60	5.20 ± 0.06^{gfieh}	0.61 ± 0.01^{i}	33.45 ± 0.09^{h}	20.49 ± 0.005^{i}	14.29 ± 0.06^{i}	6.21 ± 0.01^{i}

	Oven	90	5.09 ± 0.02^{gdfce}	0.78 ± 0.005^{e}	38.85 ± 0.05^{d}	31.11 ± 0.03^{d}	23.85 ± 0.04^{d}	7.26 ± 0.01^{d}
	Sun	Initial	5.41 ± 0.005^{c}	0.33 ± 0.02^{p}	15.04 ± 0.052^{t}	11.97 ± 0.08^{w}	9.03 ± 0.03^{o}	2.94 ± 0.05^{t}
	Sun	30	5.40 ± 0.03^{dc}	0.47 ± 0.00^{l}	22.25 ± 0.055^{p}	12.31 ± 0.02^{u}	6.99 ± 0.005^{s}	5.32 ± 0.015^{m}
	Sun	60	5.13 ± 0.045^{gih}	0.45 ± 0.00^{m}	30.81 ± 0.12^{j}	17.73 ± 0.01^{n}	11.25 ± 0.006^{l}	6.49 ± 0.006^{g}
	Sun	90	5.14 ± 0.02^{gih}	0.54 ± 0.01^{j}	35.73 ± 0.045^{e}	21.95 ± 0.02^{g}	14.73 ± 0.015^{h}	7.23 ± 0.005^{d}
Treated with 60°Brix sugar conc.	Oven	Initial	5.40 ± 0.02^{dce}	0.39 ± 0.005^{e}	16.09 ± 0.06^{s}	20.19 ± 0.07^{J}	16.17 ± 0.04^{f}	4.03 ± 0.025^{q}
	Oven	30	5.42 ± 0.01^{c}	0.65 ± 0.005^{g}	27.81 ± 0.061^{l}	16.39 ± 0.015^{P}	10.51 ± 0.02^{m}	5.89 ± 0.006^{j}
	Oven	60	6.16 ± 0.05^{a}	0.63 ± 0.00^{h}	39.04 ± 0.14^{c}	31.64 ± 0.006^{c}	24.88 ± 0.005^{c}	6.77 ± 0.006^{f}
	Oven	90	5.41 ± 0.02^{c}	0.82 ± 0.00^{b}	44.85 ± 0.015^{a}	47.75 ± 0.006^{a}	39.99 ± 0.006^{a}	7.75 ± 0.01^{c}
	Sun	Initial	6.19 ± 0.015^{a}	0.29 ± 0.005^{r}	18.64 ± 0.015^{q}	12.13 ± 0.015^{v}	8.56 ± 0.005^{q}	3.57 ± 0.01^{r}
	Sun	30	5.59 ± 0.22^{gdfieh}	0.34 ± 0.005^{q}	26.42 ± 0.01^{m}	15.13 ± 0.005^{r}	8.76 ± 0.01^{p}	6.37 ± 0.0^{2h}
	Sun	60	5.21 ± 0.18^{b}	0.52 ± 0.01^{k}	34.55 ± 0.045^{f}	27.57 ± 0.06^{e}	19.28 ± 0.055^{e}	8.28 ± 0.006^{b}
	Sun	90	5.14 ± 0.005^{gih}	0.87 ± 0.51^{c}	44.14 ± 0.04^{b}	34.00 ± 0.03^{b}	25.65 ± 0.01^{b}	8.35 ± 0.02^{a}
CV (%)			1.96	1.19	0.035	0.2	0.26	0.55

NB: Means followed by the same letter within a column are not significantly different from each other at 5% level of significance. CV: Coefficient of Variation; pH: Hydrogen ion concentration; TA: Titrable Acidity; TSS: Total Soluble Solid; TS: Total Sugar Content; RS: Reducing Sugar; NRS: Non-Reducing content

DISCUSSION

Chemical composition

Chemical composition content of the banana chips are presented in Tables 1 and 2. The initial moisture content of banana chips was different for different treatments and ranged between 15.97 to 17.97%. The banana chips treated with sugar syrups had comparatively lower initial moisture content 15.97 to 16.85% as compared to untreated banana chips (17.82 to 17.97). This might be due to osmotic pressure in the osmotic solution which forced water out or removing of water from the internal tissues even before drying. Oven-dried banana chips recorded the lowest moisture content as compared to open sun drying. This might be due to high temperature applied for a moderately short drying time compared to the open sun drying. The interactions of osmotic treatment, drying methods and storage period on the moisture content are presented in Table 1. Values of moisture contents were significantly ($p<0.0001$) different due to interaction effect of osmotic treatment, drying methods and storage period. Moisture of the stored product of different treatments ranged from 15.97% to 19.38%. The minimum moisture content 15.97% was observed in oven dried product treated with 60°Brix of sugar syrup and evaluated at initial storage period whereas maximum moisture content of 19.38% was recorded in untreated sun dried product and evaluated at 90th day of storage period. Moisture content of banana chips gradually increased in all the samples during storage period at room temperature. This might be due to variation of the storage temperatures and relative humidity. Hygroscopic nature of the chips and environmental humidity might also have facilitated moisture absorption from the surrounding environment.

The data presented in Table 1 shows a significant ($p<0.0001$) difference in crude fiber content of banana chips due to the interaction effect of osmotic treatment, drying method and storage period. Perusal of Table 1 reveals that both drying methods and osmotic treatments had an effect on the percentage of crude fiber content of the chips. The initial crude fibre content of chips in different treatments ranged from 17.97 to 29.47%. A gradual decline in crude fiber content was observed in all treatments during storage period. The lowest value of Crude fiber (2.98%) was recorded at 90th days storage interval in osmotically treated oven dried fruit treated with 60° Brix whereas maximum crude fiber content of banana chips (29.47%) was recorded in untreated oven dried banana chips at initial storage time (0 days). A continuous declining trend in crude fiber with increasing storage period is clearly indicated in Table 1. This could be due to the ability of the sugar molecules in the osmotically dried sample to bind and form a complex with some of the water molecules in the banana chips, thereby making it less fibrous and diffusion of osmotic treatment to the banana chips on solutes.

Drying method and osmotic treatment had a significant influence on ash content of dried chips. The data presented in Table 1 showed that a significant ($p<0.0001$) difference in ash content of banana chips due to the interaction effect of osmotic treatment, drying method and storage period exists. The initial ash content of banana chips prepared by different treatment combinations varied significantly and ranged between 4.33 to 5.94 %. The untreated chips had a higher initial ash content compared to treated chips. The concentration of sucrose treatment too had an effect on ash content of the chips. Chips prepared with 60° Brix sugar syrup treatment had lower initial ash content compared to chips prepared with 30° Brix syrup treatment. The data indicates a significant decrease in ash content during storage under all treatments. The maximum value (5.94%) of ash content was observed in untreated oven dried banana chips at initial day storage period, whereas the minimum value (1.64%) was recorded in sun dried chips treated with 60° Brix at 90^{th} day's storage. Decrease in ash content of banana chips in the all treatments might be due to moisture absorption during storage period and leaching of some minerals from banana chips during osmo dehydrated process.

Banana chips prepared by different treatments had different initial crude protein content, ranging from 1.55% (treated with 60° Brix syrup dried in oven) to 2.99% (in untreated sun dried). The banana chips treated with sugar syrups had comparatively lower initial protein content (1.55-2.90%) as compared to untreated banana chips (2.35-2.99). This might be due to greater protein solubilization during osmotic treatment at higher concentration of sugar which resulted in the removal of more water from the tissues. Higher protein content was observed for the sample dried in oven when compared to those of sun dried banana chips. The data presented in Table 1 indicated significant ($p<0.0001$) changes in crude protein content of banana chips due to the interaction effect of osmotic treatment, drying method and storage period. Though generally a decreasing trend in crude protein content was observed during storage but in certain treatments the changes were not consistant and in such cases even an increase at certain storage intervals was recorded. The maximum value (3.51%) of crude protein content in banana chips was recorded in untreated oven dried banana chips at 30^{th} day of storage period whereas the minimum value (1.06%) of crude protein was recorded at 90^{th} days of storage sun dried chips treated with 60° Brix sugar syrup. Decrease in crude protein content might be due to formation of complex compound from free amino acid in the protein and sugar molecules through Millard reaction, leading to unavailability of protein for quantitative measurement.

As observed in Table 1 the initial crude fat content of banana chips prepared by different treatments was different for each treatment. Initially the crude fat content ranged from 0.39 to 0.76 %. The banana chips treated with sugar syrups had comparatively lower initial crude fat content (0.39-0.67%) as compared to untreated banana chips (0.43-0.76%). Table 1 also shows the mean values of crude fat as affected by the drying method. The fat content of sun dried samples is higher as compared to oven drying. This might be due to degradation of the total fat composition of banana chips and this might have been due to leaching and oxidative losses during osmotic treatment and drying respectively. The data presented in the Table 1 further indicates that crude fat content in the chips significantly ($p<0.0001$) decreased in all treatments during storage. The interaction effect of osmotic treatment, drying method and storage period is also reflected as. The maximum value (0.76%) of crude fat of banana chips was recorded in untreated sun dried banana chips at initial day of storage whereas minimum value (0.01) of fat was observed at 90^{th} days of storage dried in oven and sun treated with 30 and 60° Brix sugar syrup of banana chips.

The carbohydrate contents of banana chips were significantly ($p<0.0001$) affected by the osmotic treatments, drying methods and storage period and their interaction is presented in Table 1. The initial values of carbohydrate content for different treatments were different. These values ranged from 47.01 to 59.21% in different treatments. The untreated (control) banana chips had the lowest carbohydrate content as compared to the treated banana chips. This might be due to use of sugar as an osmotic solution which resulted in increasing their carbohydrate content. Sun dried banana chips had the lowest carbohydrate content as compared to oven dried banana chips. This might be due to regular application of heat increases the carbohydrate content of the banana chips. It is observed from the Table that carbohydrate increased in all treatments during storage. The highest carbohydrate 72.39% content was observed in oven dried banana chips treated with 60°Brix sugar at 90^{th} day of storage. Whereas the lowest carbohydrate content 47.01% of banana chips was observed in untreated oven dried banana at initial storage period (0 days). Increase in carbohydrate content might be due to variation in other parameters during storage period.

As observed in Table 2 the initial pH content of banana chips prepared by different treatments was different. Initially the pH content ranged from 5.27 to 6.19. Banana chips treated with sugar syrups had comparatively higher initial pH content (5.27-6.1967) as compared to untreated banana chips (5.37-5.46). This might be due to leaching of soluble acids into the water during addition of sugar solution to the slices. There was a significant difference in pH values of banana chips prepared by different methods. The data indicated that the pH of banana chips was higher in open sun drying as compared to oven drying method (Table 2). This might be due to the slow drying process which leads to degradation of organic acids. Osmotic treatment, drying method and storage period had significantly ($p<0.0001$) affected the pH of banana chips. Perusal of data pertaing to pH values as given in Table 2, it is observed that sun dried banana chips pretreated with 60°Brix syrup had maximum pH value of 6.19 at initial day of storage period, whereas sun dried untreated banana chips had minimum pH value of 5.02 at 90^{th} day of storage. Changes in pH are observed during storage in all treatments, though in most cases the pH has decreased during storage period. This might be due formation of acid during storage.

As observed in Table 2 the initial TA content of banana chips prepared by different treatments was different for each treatment. Initially the TA content ranged from 0.29 to 0.55% expressed as malic acid. Banana chips treated with sugar syrups had comparatively lower initial titratable acidity content (0.29-0.39%) as compared to untreated banana chips (0.47-0.55). This might be due to leaching of organic acid during osmotic solution process. And also drying method affects the titratable acidity of banana chips significantly. The results indicated that oven dried banana chips had higher acidity as compared to sun dried banana chips. This might be due to regularly drying process which leads to increment of organic acids. Titrable acidity of banana chips as influenced by osmotic treatment, drying methods and storage periods are presented in Table 2. There was a significant ($p<0.0001$) difference between titrable acidity of the banana chips due to interaction effect of osmotic treatment, drying method and storage period. During storage maximum mean value of titratable acidity (0.88%) in banana chips was recorded in untreated oven dried chips at 90^{th} day of storage period, whereas the minimum value of (0.29%) of titrable acidity was recorded in the initial day (0 storage) sun dried chips treated with 600 Brix sugar syrup. Perusal of the data reveals that in general there was an increase in the acidity of banana chips prepared by various treatments. Increase in acidity of stored banana chips in the present studies is also justified by the decrease of pH during storage. This might be due to formation of acidic compound by degradation or oxidation of reducing sugar or breakdown of pectic substance into acids during processing or storage.

TSS data of banana chips is presented in Table 2 and showed significant ($p<0.0001$) difference among its mean values due to the interaction effect of osmotic treatment, drying method and storage period. The sugar concentration in the syrup used for osmotic pretreatments had a much greater influence on the initial TSS of banana chips. Initial TSS values of different treatments reveal that TSS of untreated chips was 10.850B for oven dried and 10.390B for sun dried chips, whereas the corresponding values of TSS for 30°Brix and 60°Brix syrup treated chips was 15.020B and 15.040B and 16.090B and 18.640B respectively. Thus it is clear that syrup treatment and its concentration had greater influence on TSS. Total soluble solid of banana chips dried by oven drier had higher as compared to open sun drying. TSS in all treatments increased during storage. The maximum TSS of 44.850B was recorded at 90^{th} day of storage in the oven dried product prepared after treating the sliced banana with 60°Brix sugar syrup. TSS in dehydrated banana chips gradually increased in all the treatments during advancement of storage period.

Total sugar content of banana chips is presented in Table 2. The combinations effect of osmotic treatment, drying methods and storage periods showed significant ($p<0.0001$) differences in the total sugar content. The initial total sugar content of different treatments ranged between 10.65 to 20.19%, indicating that osmotic treatment and drying methods had influenced the total sugar content. As a general observation it was observed that initial total sugar content of banana chips dried in oven was comparatively higher than sun dried chips for each corresponding treatment. During storage the total sugar content of banana chips significantly increased as shown in Table 2. The maximum value (47.75%) of total sugar was recorded at 90^{th} day in oven dried chips treated with 60°Brix, whereas minimum (10.65%) total sugars in banana chips was recorded in untreated oven dried chips on the first day (0storage). Total sugars in all the treatments increased with advancement in storage period. This might be due to hydrolysis of starch.

The data presented in Table 2 showed significant ($p<0.0001$) differences in reducing sugar due to the combined effect of osmotic treatment, drying method and storage period. Initially the values of reducing sugars prepared by different treatments ranged between 6.68 and 16.17, thus indicating a significant difference on reducing sugars as an effect of different treatments. During storage the reducing sugar of banana chips increased with the advancement of storage period in all the treatment combinations. The maximum value 39.99% of reducing sugar was noticed on 90^{th} day of storage in oven dried chips treated with 60°Brix, whereas minimum value of 6.68% was recorded in untreated oven dried chips at initial day (0 day). Increase in reducing sugars during storage might be due to conversion of non-reducing sugars to reducing sugars. Like total and reducing sugars the initial values of non-reducing sugars were also different for different treatments.

Non reducing sugars ranged from 2.94 in sundried chips pretreated in 30°Brix syrup to 4.28 % in untreated oven dried chips. Thus it is observed that both pretreatment and drying methods influenced the non-reducing sugar content of banana chips. Non-reducing sugar of banana chips is presented in Table 2 and shows significant ($p<0.0001$) difference among its mean value due to the combination effect of osmotic treatment, drying method and storage period. The non reducing sugar significantly increased with the advancement of storage period irrespective of both drying methods and osmotic treatments. The maximum value (8.35%) of non-reducing sugar was observed at 90^{th} day of storage in sun dried chips treated with 600 Brix, whereas minimum value (2.94%) of non-reducing sugar was recorded as an initial value (0 days storage) in sun dried chips treated with 30°brix sugar syrup. Perusal of Table 2 clearly reveals that in general an increasing trend in non-reducing sugars was evident during storage of banana chips. This might be due to breakdown of starch into non-reducing sugar and then that non-reducing sugar was converted into reducing sugar.

CONCLUSION

The varying levels of osmotic treatment, drying method and storage period produced different chemical composition parameters of statistical significance. All the osmotic treatment, drying method and storage (in combination) of 60°Brix, oven dried and initial day of storage respectively, resulted in the best chemical composition of banana chips. The sugar syrup treatment of banana chips was found to yield chips of better quality. Significant ($p<0.0001$) storage changes were observed in all treatments. Total Soluble Solids (TSS) and total, reducing and non-reducing sugars increased in all treatments during storage. Acidity increased but pH decreased during storage. It is concluded that banana chips prepared after osmotic treatment can yield a product of better chemical composition. The product will also retain the acceptability attributes for a longer time compared to the products prepared without any treatments.

In view of the present finding it is recommended that, for preparation of banana chips it is better to apply pretreatment of soaking banana slices in sugar syrup for a period of 18 hours. This will help to improve nutritive value of banana chips. Common farmers, who cannot afford a high investment on driers or ovens, can use open sun drying technique after syrup treatment. More detailed investigations need to be conducted for various product developments from banana.

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