Production of banana chips using different drying methods

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Abstract

Banana chips (sweet and salty) are consumed as an alternative breakfast cereal either fried in oil or dried. Therefore, this study was carried out to investigate the effect of using different drying methods on banana chips. They were produced in three different ways: fried in oil and dried in either a microwave oven or conventional hot air oven. Sweet and salty banana chips were evaluated for chemical composition, color, measurement of texture and sensory evaluation. The optimal conditions for fried banana chips in oil were obtained at a temperature of 160°C for 3 minutes with a slice thickness of 2 mm. As for the microwave, the sample was fried at power 7 for 7 minutes. The oven fried sample was done at 70°C for 30 minutes. The results indicated that moisture and fat content increased significantly in sweet and salt banana chips fried in oil. However, ash and fiber content were significantly decreased in oil-fried banana chips and increased in both oven and microwave-banana fried chips. The protein content in oven-fried banana chips was significantly higher. The color of sweet and salt microwave-banana fried chips were higher in Lightness (L) values and lower in redness (a) values. The hardness increased in sweet oven-fried and salty microwave-banana fried chips. Regarding sensory evaluation, most of the panelists reported that salty microwave-fried and sweet oil-fried banana chips were more acceptable. Accordingly, this study recommends using microwave and conventional hot air oven in banana chips production.

Keywords :chips, banana, frying, oven, microwave, chemical composition, color, sensory evaluation.

INTRODUCTION

Banana (*Musa paradisiaca L*.) is the common name for herbaceous plants of the genus Musa. "banana" usually refers to soft, sweet "dessert" bananas. Banana plants are monocotyledonous perennial and important crops in the tropical and Subtropical world regions **(Valmgyor *et al.*, 2000).** After harvesting, the quality of bananas deteriorates rapidly. Drying is largely utilized to stabilize the product by reducing its moisture content. In addition to preservation, drying can also create a new range of products and this indeed adds value to fresh bananas. Banana chips are one of the value-added products from fresh bananas. It can be consumed as a snack or used as an ingredient in breakfast cereal (**Prachayawarakorn *et al.*, 2008)**.

Most people consume it raw, steaming or boiling. However, bananas are easily ripe, and become a huge waste to the food industry. One of the methods to process bananas is to make banana chips. Banana chips are processed using deep-fried or dried slices of bananas. The chips can be covered with sugar or honey and have a sweet taste, or they can be fried in oil and spices and have a salty or spicy taste. Usually, the chips are produced from unripe bananas, of which slices are deep-fried in palm oil or coconut oil, which are dry (like potato chips). If ripe bananas are used, they come out oily. They are used for dessert, not for dry chips. Visual color is the major quality criterion for determining commercial quality with respect to consumers' preferences and cost of the chips **(Abdullah, 2014).**

Drying is the process of removal of moisture from the product to the predetermined level. It is the traditional method for extending the shelf life of the product. Drying can cause reduction of water activity, and thereby it reduces the contamination caused by microorganisms **(Deepak *et al.* 2020).** Several techniques have been developed to preserve bananas. Several drying technologies have been used: sun-drying; hot air-drying; freeze-drying and the deep-frying process. One of the most preferred commercial dried banana products is the banana chip which is normally produced by a deep-

frying process **(Fasano & Mancini, 2007; Yamsaengsung & Moreira, 2002a, 2002b).** Microwave drying has potential advantages over the conventional drying method. They are more rapid processes with more uniform heating that can lead to improved quality and higher yield, higher energy efficiency, better and faster process control, less floor space and more selective heating **(KTH., 2013).** Oven-drying is the simplest way to dry food because there is no need for special equipment. It is important to keep the oven temperature at 60˚C to 70˚C **(Reeb and Milota.,1999).** The aim of this study was to determine the effect of using different frying methods on banana chips. In addition, frying was performed in three different ways - in oil, microwave and oven - and chemical analysis, color analysis and sensory evaluation were carried out. It was also selected for impact study Pre-treatment of finished banana chips.

MATERIAL AND METHODS

A. Materials:

1. All ingredients for product preparation (oil, different spices, lemon and sugar) were purchased from the local markets.
2. **Fruits:** Green unripe bananas (*Musa Cavendish)* were obtained from Crops Research Institute. Agricultural Research Center. Ministry of Agriculture, El-Dokki, Center, Giza, Egypt.
3. **Chemicals** used for proximal determination were purchased from Chemicals Co. in Egypt.

B. Methods:

Preparation of banana chips:

Unripe bananas were peeled, cut into slices about 2 mm thick, then soaked in citric acid solution (by mixing 1 part lemon juice with 2-3 parts distilled water) for 3-5 minutes to prevent browning. The slices were removed and filtered to get rid of the solution, they were immersed in a 2% saline solution for 20 minutes for salted banana chips and immersed in a sugar solution prepared by adding (4 % sugar solution for 30 seconds for sweet banana chips) with

100 ml of distilled water for 30 seconds. Then treated samples were dried using a paper towel, according to **Mogra & Choudhary, (2014**) with some modifications.

C. Cooking methods:

1. **Frying:** Banana slices were fried in a deep fryer using sunflower oil at a temperature of 160°C for 3 minutes until the banana chips turned brown.
2. **Microwave Cooking:** banana slices were cooked in a microwave oven (TFB9730, Bosch, Germany) at power (10, 7, 5, 3) for (7, 5, 3) minutes.
3. **Oven Frying:** Banana samples were dried by conventional hot air oven at three temperatures (60, 70 & 80 °C). Samples were cooled and weighed until safe moisture content was reached, packed in LDPE (Low-density polyethylene) bags and stored in a cool and dark place before determining quality factors.

D. Chemical Composition: Bananas were subjected to chemical analysis including protein, moisture, fat, ash and total fiber according to **A.O.A.C (2005),** and carbohydrates were calculated with the difference. Total calorie content of the product was calculated.

E. Mineral composition: Mineral content (Ca and Mg) of samples was determined using atomic absorption apparatus (PUG 100 X series Atomic Absorption spectrophotometer) (PERKIN ELMER) using the methods described by the **AOAC (2005).**

F. Quality evaluation

1. **Color analysis:** The color of the different frying samples was measured according to **Hunter, (1975),** a spectrophotometric colorimeter (Tristimulus Color Machine) with a CIE Laboratory colorimeter (Hunter, Lab Scan: -Scott (Hunter, 1975) as follows: $\Delta E = (\Delta a^2 \pm \Delta b^2 \pm \Delta L2)^{1/2}$

Where a = a –ao., b= b- bo., and L=L - LO The letter "O" indicates the control color, and the hue angle (tan-1 b/a) and saturation index [$\sqrt{(a^2 \pm b^2)}$] were calculated.

2. **Measurement of Texture:** Texture (mm/sec) of sweet and salted banana chips was measured by using Penetrometer apparatus, Model H-1240 with serial number of 99101240 specs: Ast M, Humboldt MFG, Co., U.S.A. according to **Penfield and Campbell (1990)** at Nutrition and Food Science laboratory, Faculty of Home Economics, Helwan University. The method was based on determination of the distance (mm) a cone penetrates a sample (banana chips) during a defined period of time (sec) as an indication for product tenderness.
3. **Sensory evaluation:** Sensory evaluation was determined to detect appearance, taste, odor, crunch, color, general acceptability. Organoleptic evaluation was carried out on 10 well-trained members (from the Department of Nutrition and Food Science, Faculty of Home Economics) using a score sheet. All characteristics were rated from 1-10 (1= very poor and 9 and 10= very good and overall acceptability) according to **Penfield & Campbell, (1990).**
4. **Statistical analysis:** The statistical analysis was carried out using SAS statistical software and the results were expressed as (mean ±SE). Data were analyzed by one way analysis of variance (ANOVA). The differences between means were tested for significance using the least significant difference test (LSD) at ($P < 0.05$) **(SPSS, 1986).**

RESULTS AND DISCUSSION

1. Chemical Composition

The nutritional value of sweet and salted banana chips was analyzed and their proximate compositions are presented in Table (1) and Figures (1) and (2). The protein content in oven-fried banana chips was significantly higher for both sweet (3.02 g/100 g) and salted

(3.07 g/100 g) as compared to microwave-fried banana chips (2.87 and 2.27 g/100 g) and oil-fried banana chips (2.69 and 2.91 g/100 g) respectively as shown in Figure (1). These results revealed that chips were exposed to high temperatures and increased fat absorption during frying may lead to a slight decrease in protein content, due to deterioration in the quality of proteins. These findings agree with the study conducted by **Saguy and Dana (2003)**, which reported that during frying, oil uptake occurs in addition to various chemical and physical changes caused by hydrolysis, oxidation, and thermal decomposition. Similarly, **Bordin *et al.*, (2013)** who noted that the frying process dehydrates foods, resulting in significant physical and chemical transformations, including starch gelatinization and protein denaturation.

Moreover, it was clearly noticed that there was significant increase in fat content for both sweet (3.02 g/100 g) and salt (3.36 g/100 g) oil-fried banana chips as compared to microwave-fried (0.95 and 1.05 g/100 g) and oven-fried banana chips (0.78 and 1.10 g/100 g) respectively as indicated in Figure (1). Meanwhile the results obtained from the previous table and Figure (2) show that carbohydrate (by difference) content of oven-fried banana chips was higher significant increase for both sweet (82.54 g/100 g) and salt (84.26 g/100 g) as compared to microwave-fried sweet and salt (81.93 and 83.84), and oil-fried banana chips (80.28 and 81.93 g/100 g) respectively.

In addition, the presented data in the same table and Figure (1) indicates a significant increase in ash content in microwave-fried (4.02 and 3.47 g/100 g for sweet and salt banana chips, respectively) and oven-fried banana chips (3.85 and 3.25 g/100 g, respectively) compared to oil-fried banana chips which had significant decrease in ash content (3.51 and 3.07 g/100 g for sweet and salt banana chips, respectively). These findings could emphasize the effect of microwave and oven frying in retaining nutritional quality (mineral content) of food products, as compared to oil frying.

Table (1): Nutritive value (g/100 g) of banana chips prepared with sweets and salt and fried by different methods.

Samples		Sample Fried by:		
		Oil	Microwave	Oven
Protein	Sweet	$2.69^{c}\pm 0.39$	$2.87^{b}\pm 0.48$	$3.02^{a}\pm 0.51$
	Salt	$2.91^{a}\pm 0.89$	$2.27^{b}\pm 0.78$	$3.07^{c}\pm 0.51$
Fat	Sweet	$3.02^{a}\pm 0.51$	$0.95^{b}\pm 0.66$	$0.78^{b}\pm 0.41$
	Salt	$3.36^{a}\pm 0.62$	$1.05^{c}\pm 0.51$	$1.10^{b}\pm 0.36$
Carbohydrate	Sweet	$80.28^{c}\pm 0.24$	$81.93^{b}\pm 0.38$	$82.54^{a}\pm 0.41$
	Salt	$81.93^{b}\pm 0.21$	$83.84^{a}\pm 0.71$	$84.26^{ab}\pm 0.41$
Ash	Sweet	$3.51^{b}\pm 0.58$	$4.02^{a}\pm 0.42$	$3.85^{a}\pm 0.56$
	Salt	$3.07^{c}\pm 0.32$	$3.47^{b}\pm 0.48$	$3.25^{c}\pm 0.72$
Fiber	Sweet	$5.25^{b}\pm 0.42$	$5.75^{ab}\pm 0.51$	$5.92^{a}\pm 0.71$
	Salt	$4.82^{b}\pm 0.29$	$5.25^{a}\pm 0.71$	$5.05^{ab}\pm 0.49$
Moisture	Sweet	$4.91^{a}\pm 0.56$	$4.48^{b}\pm 0.66$	$4.27^{c}\pm 0.86$
	Salt	$3.64^{a}\pm 0.51$	$3.31^{c}\pm 0.25$	$3.01^{b}\pm 0.31$

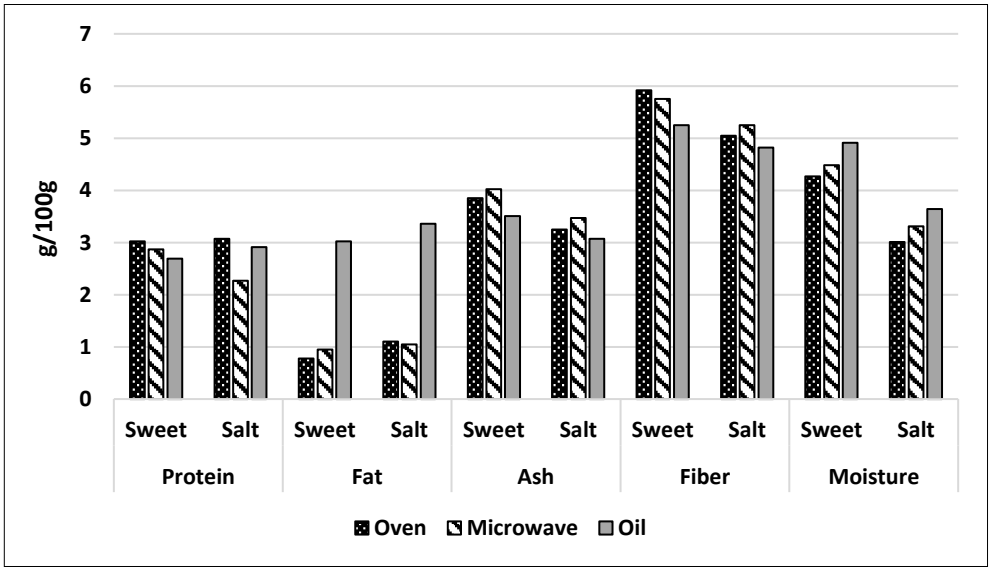

Figure (1): Chemical composition (g/100 g) of banana chips (sweets and salt)

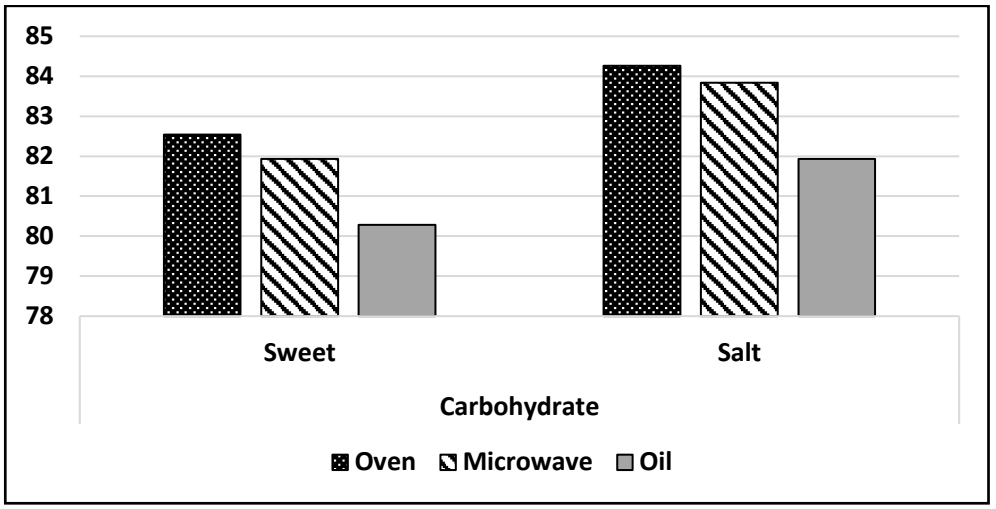

Figure (2): Carbohydrate composition (g/100 g) of banana chips (sweet and salt)

The data presented in Table (1) and Figure (1) indicates a slight increase in dietary fiber content in banana chips fried in the oven (5.92 and 5.05 g/100 g for sweet and salt banana chips, respectively) and in the microwave (5.75 and 5.25 g/100 g, respectively). However, oil frying resulted in a significant decrease in fiber content (5.25 and 4.82 g/100 g for sweet and salt banana chips, respectively) as compared to fried oven. This reduction may be attributed to the slight interaction between fiber and fats during frying, leading to a decrease in fiber content. In contrast, oven and microwave frying had minimal impact on fiber retention. These findings are consistent with the observations of **Dana and Saguy (2006)**, who investigated how deep-fat frying affects interactions between food components, including fiber and fats, which can alter food composition. Similarly, **Krokida *et al.* (2000)** reported that frying influences water loss in food, which may affect the retention and apparent content of components like fiber.

On the other hand, oil frying led to a significant increase in moisture content (4.91 and 3.64 g/100 g for sweet and salt banana chips, respectively) compared to microwave frying (4.48 and 3.31 g/100 g for sweet and salt banana chips, respectively) and oven frying (4.27 and 3.01 g/100 g for sweet and salt banana chips, respectively)

as shown in Table (1) and Figure (1). Both microwave and oven frying resulted in a notable reduction in moisture content compared to oil frying.

Table (2) Mineral contents in different chips fried by oil, microwave and oven (mg/100g)

Samples	Samples chips	Ca	Mg
Salted Banana Chips	Oil	2.010	11.576
	Microwave	2.019	11.583
	Oven	2.015	11.579

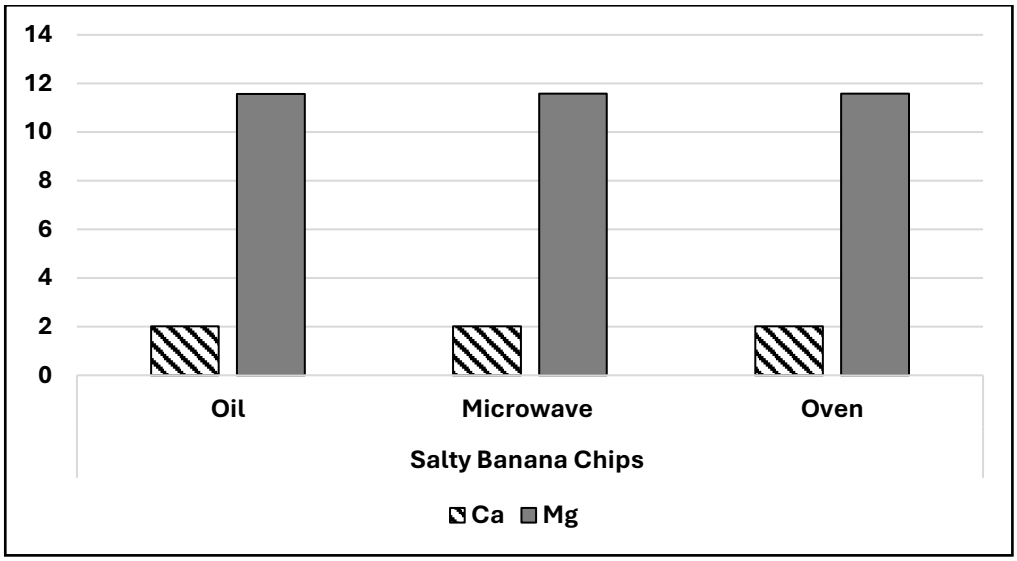

Figure (3): Calcium and magnesium composition of salty banana chips

As shown in Table (1) and figure (1), the ash content in microwave-fried and oven-fried samples was higher than that of oil-fried chips. Consequently, the estimation of calcium content was lower in salted banana chips (2.019 and 2.015 mg/100 g) respectively, magnesium content showed increase (11.583, 11.579 mg/100 g) in salty bananas fried in microwave and oven respectively. Otherwise oil-fried showed a minor decrease in Ca and Mg content. These results demonstrated that microwave-fried samples retained the highest mineral levels, followed by oven-fried samples. In contrast,

oil-fried samples exhibited the lowest calcium and magnesium content. **Karimian-Khosroshahi, et.al., (2016)** and **Razzak., et. Al., (2023)** reported that microwave frying could preserve mineral content better due to shorter cooking times while prolonged exposure to high temperatures in the oven and frying oil may lead to some loss of minerals, resulting in slightly lower ash content. From these results, it could reveal that the impact on minerals such as calcium and magnesium is relatively minor across all the mentioned cooking methods, as these elements are heat-stable and do not decompose.

Quality Evaluation of Products:

1. Color Evaluation

The results in the table (3) and figure (4) show the color values of banana chips (sweet), fried in three different ways in oil, microwave, and oven. The color values were measured by Hunter colorimeter and recorded as lightness (L), redness (a), yellowness (b), saturation and hue which were calculated from the last values of (L, a, b).

The lightness (L) values indicated that sweet microwave-fried banana chips were significantly higher (52.35) as compared to oil-fried chips (42.63), while oven-fried chips had the lowest lightness value (33.65). While the highest redness value (a) was found in the oven-fried samples (8.95), followed by oil-fried samples (7.35), and microwave-fried samples showed the least redness (6.20). For yellowness (b), the oven-fried chips had the highest yellow value (18.22), while the oil-fried samples (16.14) were more yellow than the microwave-fried samples (11.12).

Moreover, the saturation index, which assesses color intensity based on Hunter's a and b values, revealed that the oven-fried samples had the highest saturation value (20.30), significantly greater than the oil-fried samples (17.73). Meanwhile, microwave-fried samples exhibited the lowest saturation value (12.73). Regarding hue, which relates the redness (a) to yellowness (b), the oil-fried chips had the highest hue value (65.52), followed closely by the oven-fried samples

(63.84). The microwave-fried samples had the lowest hue rating (60.86).

Table (3): Hunter color values of sweet banana chips fried with different methods.

Parameters	L	a	b	a/b	Saturation	Hue
Fried by oil	42.63	7.35	16.14	0.46	17.73	65.52
Fried by microwave	52.35	6.20	11.12	0.55	12.73	60.86
Fried by oven	33.65	8.95	18.22	0.49	20.30	63.84

Where, L=lightness, A=redness, b=yellowness

Table (4): Hunter color values of salted banana chips fried with different methods.

Parameters	L	a	b	a/b	Saturation	Hue
Fried by oil	43.51	7.65	16.28	0.46	17.99	64.83
Fried by microwave	53.11	6.01	10.90	0.55	12.45	61.12
Fried by oven	31.81	9.21	19.10	0.48	21.20	64.26

Where, L=lightness, A=redness, b=yellowness

From table (4) and figure (4), the data presents the lightness (L) values of salted banana chips, indicating that microwave-fried samples (53.11) were higher than oil-fried samples (43.51), while oven-fried samples had the lowest lightness value (31.81). Whereas redness (a) value, the oven-fried samples had the highest value (9.21), followed by oil-fried samples (7.65), while microwave-fried samples had the lowest redness (6.01). Regarding yellowness (b), oven-fried chips had the most yellow value (19.10), as compared to oil-fried chips (16.28), while microwave-fried chips had the lowest yellowness (10.90).

The saturation index, which measures color intensity based on Hunter's a and b values, showed that oven-fried samples had the highest saturation value (21.20), higher than oil-fried samples (17.99). In contrast, microwave-fried samples exhibited the lowest saturation value (12.45). Finally, the hue angle, which reflects the

relationship between redness (a) and yellowness (b), indicated that microwave-fried samples had the lowest hue value (61.12). Oil-fried samples had a higher hue value (64.83) as compared to oven-fried samples (64.26).

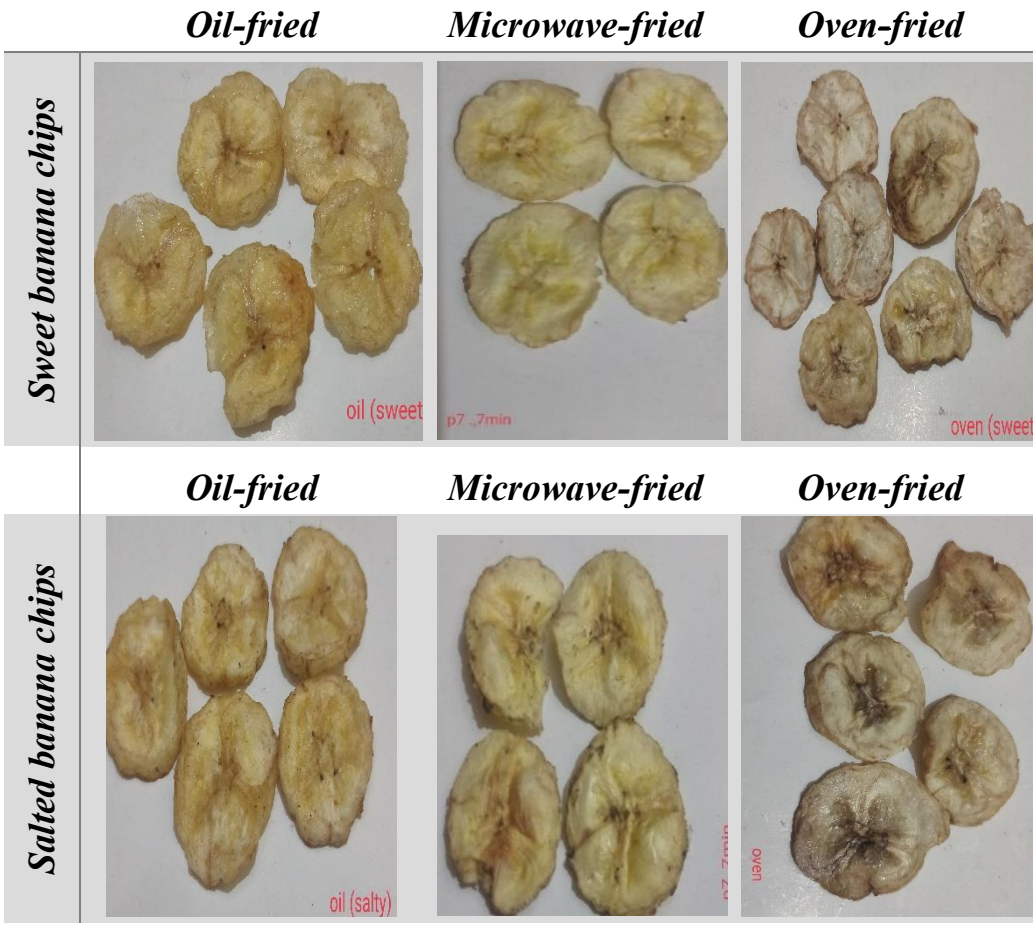

Figure (4): *Oil, Microwave and Oven-fried banana chips (sweet and salted)*

2. Measurement of Texture

Table (5) shows the texture of sweet banana chips fried in different methods. The oven-fried samples exhibited superior texture scores (86.5 mm/sec.), followed by the oil-fried samples, while the microwave-fried samples had the lowest value (43.3 4 mm/sec. and 33.4 mm/sec., respectively). Most of the moisture evaporated from the bananas during frying, resulting in a crispy texture. This parameter is critical for evaluating the quality of banana chips, as textural firmness is assessed by measuring breaking force. Breaking force is a reliable indicator of the Crunch of vacuum-fried chips **(Fan *et al.*, 2005)**. Crunch in banana chips is achieved when a crust forms on the surface **(Farkas *et al.*, 1996).**

Table (5): The effect of different frying methods on texture measurement (mm/sec.) on sweet and salted banana chips.

Samples	banana chips (sweet)	banana chips (salt)
Fried by oil	$43.3^{b} \pm 0.63$	$12.25^{c} \pm 0.43$
Fried by microwave	$33.4^{c} \pm 0.55$	$39.75^{a} \pm 0.69$
Fried by oven	$86.5^{a} \pm 1.21$	$15^{b} \pm 0.47$

For the salted banana chip samples, Table (5) shows a lower significant difference between the oil-fried and oven-fried samples (12.25 and 15 mm/sec., respectively), as compared to the microwave-fried samples which increased significantly on the texture scale (39.75 mm/sec.). The application of microwave radiation enhanced moisture diffusion from the chip surface into the atmosphere. Rapid evaporation at the surface likely contributed to higher pore density, resulting in increased crispness. Interestingly, reducing the vacuum frying (VF) time to 25 min. combined with a microwave (MW) time of 5 min. (VF25MW5) resulted in chips that were crunchy, although this was not detectable by tissue analyzer **(Jumras *et al.*, 2020).**

3. Sensory evaluation.

The quality of banana chips was evaluated through sensory analysis, including appearance, taste, odor, crunchiness, color, and overall acceptability. Results of sensory evaluation for three different

fried methods of sweet and salted banana chips are presented in Tables (6 and 7). Sensory evaluation is an aspect of greatest importance since consumer acceptance usually encourages the marketing process of new products.

Table (6) demonstrated that there were significant differences between all different fried methods ($p<0.05$) in the appearance, odor, color, taste, crunchiness and general acceptability of banana chips. It was noticed that the highest scores (mean ± SE) for appearance were given to banana chips fried by oil 8.4±0.21 followed by banana chips which were fried by microwave 7.7±0.18 while the lowest value was recorded for banana chips fried by oven 4.9±0.13. These results are in agreement with **Kumar and Shikha (2020)** who compared different techniques such as frying, baking, and roasting on banana chips and emphasized how oven frying may result in less desirable characteristics in appearance compared to oil frying due to moisture loss and uneven heat distribution.

Table (6): Effect of different frying methods on sensory evaluation of sweet banana chips

Characteristics	Samples		
	Fried by oil	Fried by microwave	Fried by oven
Appearance	$8.40^{a} \pm 0.21$	$7.70^{b} \pm 0.18$	$4.90^{c} \pm 0.13$
Taste	$7.95^{a} \pm 0.20$	$7.30^{ab} \pm 0.19$	$5.50^{b} \pm 0.15$
Odor	$7.50^{a} \pm 0.22$	$7.00^{b} \pm 0.17$	$6.25^{c} \pm 0.16$
Crunchiness	$7.80^{a} \pm 0.24$	$7.60^{ab} \pm 0.21$	$5.80^{b} \pm 0.13$
Color	$8.35^{a} \pm 0.27$	$7.70^{b} \pm 0.24$	$4.60^{c} \pm 0.11$
General acceptability	$8.20^{a} \pm 0.28$	$8.00^{ab} \pm 0.25$	$5.30^{b} \pm 0.14$

Table (7). Effect of different frying methods on sensory evaluation of salted banana chips

Characteristics	Samples		
	Fried by oil	Fried by microwave	Fried by oven
Appearance	$8.30^{b} \pm 0.51$	$8.50^{a} \pm 0.49$	$6.90^{c} \pm 0.39$
Taste	$7.50^{b} \pm 0.41$	$8.25^{a} \pm 0.52$	$7.00^{c} \pm 0.42$
Odor	$7.80^{ab} \pm 0.48$	$7.90^{a} \pm 0.45$	$6.75^{b} \pm 0.35$
Crunchiness	$7.80^{b} \pm 0.44$	$8.00^{a} \pm 0.50$	$6.80^{c} \pm 0.37$
Color	$7.80^{b} \pm 0.42$	$8.45^{a} \pm 0.48$	$6.40^{c} \pm 0.33$
General acceptability	$8.20^{ab} \pm 0.47$	$8.40^{a} \pm 0.51$	$6.40^{b} \pm 0.33$

Table (6) demonstrated that there were significant differences between all different fried methods ($p<0.05$) in the appearance, odor, color, taste, crunchiness and general acceptability of banana chips. It was noticed that the highest scores (mean ± SE) for appearance were given to banana chips fried by oil 8.4±0.21 followed by banana chips which were fried by microwave 7.7±0.18 while the lowest value was recorded for banana chips fried by oven 4.9±0.13. These results are in agreement with **Kumar and Shikha (2020)** who compared different techniques such as frying, baking, and roasting on banana chips and emphasized how oven frying may result in less desirable characteristics in appearance compared to oil frying due to moisture loss and uneven heat distribution.

However, the taste score was found to be not significant at $p<0.05$ for banana chips fried by oil and fried by microwave (7.95±0.20 and 7.30±0.19, respectively). However, the score (mean ± SE) given for taste was lower in oven-fried banana chips (5.50± 0.15) and not significant with banana chips fried by microwave. Regarding the fried banana sample, there was a significant decrease

in the odor attribute (6.25± 0.16), followed by microwave fried sample (7.0± 0.17), while oil fried banana chips had significantly higher ($p<0.05$) odor scores (7.50± 0.22).

Meanwhile, the crunchiness values of banana chips varied according to the frying method used (oil-fried, microwave-fried, and oven-fried). The results indicated that oil-fried samples achieved the highest crunchiness score of 7.8 ± 0.24, closely followed by microwave-fried samples at 7.6 ± 0.21. In contrast, the oven-fried samples had the lowest score of 5.8 ± 0.13.

In addition, the color scores (mean ± SE) of banana chips showed significant differences based on cooking method. Oil-fried chips had the highest color score of 8.35±0.27, followed by microwave-fried chips (7.70±0.24) at a significance $p\leq0.05$. On the other hand, oven-fried chips had the lowest color score (4.60 ± 0.11) when compared to other frying methods.

Regarding overall acceptability, it was found that oven-fried banana chips had significantly lower scores (mean ± SE) (5.3±0.14), at $p \leq 0.05$ compared to other fried types (oil and microwave 8.2± 0.28 and 8.0± 0.25., respectively).

Moreover, the sensory evaluation of salted banana chips is presented in Table (7). As for appearance results, there were significant differences ($p<0.05$) among all samples, whereas the microwave-fried sample (8.50±0.49) and the oil-fried sample (8.30±0.51) and the oven-fried sample had the lowest value of appearance at 6.90±0.39. These results could be due to frying by dry heat in the oven leading to uneven cooking and drying of the banana chips, and this effect may lead to a decrease in appearance score **Kumar and Shikha (2020)**.

Microwave-fried banana chips scored the highest scores for taste (mean ± SE) (8.25 ± 0.52) as compared with other samples, followed by the salted banana chips which were fried in oil (7.50 ± 0.41). In contrast, oven-fried samples had the lowest taste rating at 7.0 ± 0.42. However, the odor score was found to be not significantly

differences at $p \leq 0.05$ for microwave-fried (7.90 ± 0.45) and oil-fried (7.90 ± 0.45) banana chips, and the odor result for oven-fried sample showed lowest score (6.75 ± 0.35).

Also, the parameters evaluated crunchiness, color and general acceptability, with microwave-fried banana chips had the highest score (8.00 ± 0.50; 8.45 ± 0.48 and 8.40 ± 0.51 respectively) followed by the oil-fried samples (7.80 ± 0.44; 7.80±0.42 and 8.20± 0.47 respectively). In contrast, oven-fried banana chips had the lowest scores from the judges for crunchiness, color and general acceptability score (6.80 ±0.37; 6.40 ± 0.33 and 6.40±0.33 respectively) as compared to microwave and fried-oil banana chips. The obtained results indicated that there were significant differences between all different frying temperature methods, except for odor and overall acceptability for fried and microwave.

CONCLUSION

Banana chips have a high marketing potential, as they represent a different source of nutrients well characterized by its mineral nutritional value and reasonable energy supply. In general, salted microwave-fried banana chips were found to be most acceptable by the panelists followed by those fried in oil. However, sweet oil-fried banana chips came in first order of preference followed by microwaved banana chips. Oven-fried banana chips (sweet and salty) were not accepted by the panelists; however, they had a higher protein content and lower fat and moisture content.

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إنتاج رقائق الموز باستخدام طرق تجفيف مختلفة

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تستهلك رقائق الموز (شيبس) (الحلوة والمالحة) كبديل لحبوب الإفطار إما مقلية في الزيت أو مجففة. لذلك، أجريت هذه الدراسة للتحقق من تأثير استخدام طرق التجفيف المختلفة على رقائق الموز. التي تم إنتاجها بثلاث طرق مختلفة: مقلية في الزيت ومجففة إما في فرن الميكروويف أو الفرن التقليدي بالهواء الساخن. تم تقييم رقائق الموز الحلوة والمالحة من حيث التركيب الكيميائي واللون وقياس الملمس والتقييم الحسي. وكانت الطريقة المثالية لتحضير رقائق الموز المقلية في الزيت عند درجة حرارة ١٦٠ درجة مئوية لمدة ٣ دقائق بسمك شريحة ٢ مم. أما بالنسبة للميكروويف، فقد تم تجفيف العينة على طاقة ٧ لمدة ٧ دقائق. وبالنسبة للعينة في الفرن تم التجفيف عند ٧٠ درجة مئوية لمدة ٣٠ دقيقة. وأشارت النتائج إلى أن محتوى الرطوبة والدهون القلي قد ارتفع بشكل ملحوظ في رقائق الموز الحلوة والمالحة المقلية فى الزيت. بينما، انخفض محتوى الرماد والألياف بشكل ملحوظ في رقائق الموز المقلية بالزيت وزاد في كل من رقائق الموز المقلية بالفرن والميكروويف. كما ارتفع محتوى البروتين في رقائق الموز المقلية بالفرن. وكان لون رقائق الموز المقلية الحلوة والمالحة في الميكروويف أعلى في قيم السطوع (L) وأقل في قيم الاحمرار (a). كما زادت الصلابة في رقائق الموز المقلية الحلوة والمالحة في الميكروويف. أما فيما يتعلق بالتقييم الحسي، أفاد معظم المحكمين أن رقائق الموز المالحة المقلية في الميكروويف والرقائق الحلوة المقلية بالزيت كانت أكثر قبولًا. وعليه، توصي هذه الدراسة باستخدام الميكروويف وفرن الهواء الساخن التقليدي في إنتاج رقائق الموز.

الكلمات المفتاحية: رقائق، الموز، القلى، الفرن، الميكروويف، التركيب الكيميائي، اللون، التقييم الحسي.