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Development of banana chips: Analysis of nutritional and sensory characteristics of banana chips as influenced by frying conditions

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A B S T R A C T

Banana (*Musa sapientum* L) is a widely grown and consumed fruit due to its distinct aroma and taste. In Ethiopia, there is a lack of knowledge and trends on the processing and consumption of processed and shelf-stable banana products. The aim of this study was to evaluate the effects of frying time and layering of *Moringa stenopetala* leaf powder on the proximate composition, oxidative stability and sensory properties of green banana chips. In this study, prepared chips from green bananas using two levels of *Moringa stenopetala* leaf powder layers (3% & 6%) and three levels of frying time (1.5, 2.0, & 2.5 minutes) following standard methods. Proximate Composition, Oxidative Stability and Sensory Properties of the chips were analyzed. The results showed that the banana chips had moisture (3.35–7.34%), total ash (5.67–13.65%), crude fiber (4.43–12.43%), crude fat (3.34–11.70%), crude protein (3.56-13.80%), carbohydrate (57.78–67.29%). Descriptive sensory analysis (DSA) showed that banana chips prepared with layering of *M. stenopetala* leaf powder was bitter, darker, rougher, and more astringent than chips fried from only banana. Banana chips fried without Moringa leaf powder for 2.5 minutes were crispier. *M. stenopetala* leaf powder layered banana chips were lower in quality and had weak acceptability compared with banana chips fried without *M. stenopetala* leaf powder. This study suggested that layering *M. stenopetala* leaf powder during prolonged frying to banana chips improves nutritional value and oxidative stabilities without compromising the sensory properties of banana chips.

Keywords: Frying time, Proximate composition, Moringa leaf powder, Green banana, Sensory properties

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Introduction

In Ethiopia, dessert banana is the major fruit crop most widely grown and consumed. It grows in several parts where the growing conditions are conducive. In Ethiopia, the Southern Nations Nationalities and Peoples' Regional State is one of the major production areas for bananas (CSA, 2014). 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 market outlets in Ethiopia (CFC, 2004). Currently, there is minimal commercial processing of bananas. Banana has medicinal and nutritional importance; most people consume fresh, steamed or boiled bananas (Kothawade, 2019). Farmers sell bananas at giveaway prices during bumper harvests, and many go to waste. Processing of banana to chips may add value to this fruit and reduce the wasted banana (Elkhalifa *et al.*, 2014).

Frying is one of the most common processing techniques to make banana chips (Wani *et al.*, 2017). Deep-frying is an established process of banana chips preparation. In a study reported by Wani *et al.* (2017) chips thickness, frying time and frying temperature affected the quality of banana chips in deep fat frying. Banana chips have been found to be inferior in protein quality and oxidative stability. It was reported that the addition of moringa leaves could improve protein levels and anti-oxidative properties of smoothies (in moringa powder-based banana beverages) (Aderinola, 2018). However, there is limited study on the influences of the addition of

Moringa stenopetala leaf powder and frying times on nutritional quality, oxidative stability and sensory properties of banana chips, with a particular focus on banana from Ethiopia. Thus, this study aims to evaluate the analysis of nutritional and sensory characteristics of banana chips as influenced by frying conditions.

Materials and Methods

Green mature banana (*Musa sapientum*) was collected from Southern Agricultural Research Institute (SARI) and *M. stenopetala* leaf was received from Arbaminch Agricultural Research Center (AARC). Oil (Amaresa: Mixture of groundnut, palm and niger seed oil) was purchased from the local market, Hawassa, Ethiopia. Mature green unripe banana (*Musa sapientum*) samples with similar mass, maturity, and ripening stages were selected and used for the experiment.

Sample preparations

M. stenopetala leaf powder was prepared in Hawsasa University's food and nutrition laboratory. The green banana was peeled, washed with soft water at room temperature and then cut into slices 2 mm thick, each weighing approximately 1 gram. The slice was immersed into 2% salt solution to prevent enzymatic browning. All slices were reshaped into the same circular pieces with a diameter of 4 cm and moringa powder was layered on the banana slice. The technique was carried out by measuring the weight of slices and 3 and 6% of *M. stenopetala* leaf powder. The half of *M. stenopetala* leaf powder was uniformly distributed on the circular pieces and the layer was on both sides of the slice; then the slices were dried in an oven dryer at 65°C for 30 minutes. The prepared and dried banana slices were deep-fried at 180°C in vegetable oil; according to (Wanakamol and Poonlarp, 2018) all fried chips were drained for 15 seconds to remove excess oil.

Treatments and experimental design

The experiment was designed as a complete factorial experiment in which the treatments consider all possible combinations of the selected levels.

Proximate analysis

The proximate contents (moisture, ash, crude fat, fiber, protein and CHO) of the banana chips were determined according to AOAC (2000) using the official method 934.06.

Pro-Vitamin A

The total carotenoid content extraction was carried out according to Imungi and Wabule (1990). Beta-carotene content was determined spectrophotometrically as described by Muchoki *et al.* (2007).

Descriptive sensory analysis

The sensory profiling of the products was performed using the generic descriptive analysis method described by Einstein (1991).

Statistical analysis

Data analyzed using factorial ANOVA with traits as an independent variable. The means were separated using Tukey's HSD test at $p<0.05$. Principal Component Analysis (PCA) for all numerical results was performed using XLSTAT version 2016.03.30882 (Addinsoft, New York).

Results and Discussion

Effect of frying time and layering of Moringa stenopetala leaf powder on proximate compositions of banana chips

The moisture content of fried banana chips varied considerably from 3.35 to 7.34 g/100g (Table 1). The chips of banana without MLP fried for 1.5 min were higher ($p<0.05$) in moisture content than all other treatments. The banana chips fried banana without MLP, banana with 3% MLP, banana with 6% MLP fried for 2.5 min and the REF had similar ($p\geq0.05$) moisture content. In general, banana chips fried with and without MLP for 2.5 min had lower moisture content than those fried with and without MLP for 1.5 min. The finding of this study is consistent with Therdthai *et al.* (2007) who reported low moisture levels in banana chips with longer frying time. The fat contents of the banana chips ranged from 3.34 to 11.70 g/100 g (Table 1). Banana chips fried for 2.5 minutes without MLP had the highest fat level. While banana chips fried with 6% of MLP for 1.5 min had the lowest fat content. This could be due to the continuous frying time, which disrupted the solid matrix thickened the crust and developed more porosity, allowing the oil to penetrate after chips were removed from the fryer (Lumanlan *et al.*, 2020). The result of protein content varied from 3.56 to 13.80 g/100g (Table 1). The highest protein level was recorded in banana chips with 6% of MLP layered banana fried for 1.5 min. The lowest protein level was recorded in banana chips fried without MLP for 2.5 min. The protein content of banana chips fried for (1.5 and 2.5) without MLP had no significant difference ($p<0.05$). Furthermore, 6% of MLP layered banana chips fried for 1.5 min had higher ($p<0.05$) protein compared to banana fried without MLP and 3% of MLP layered banana fried for (1.5 and 2.5) min and 6% of MLP layered banana fried 2.5 min. This study supported by Oke *et al.* (2018) also found that heat treatment reduces the amount of protein and destroy some amino acids, then changes the quality of protein composition of fried banana chips. The ash content of fried banana chips ranged from 5.67 to 13.65 g/100g (Table 1). The highest ash content was recorded on banana chips fried with 6% MLP for 2.5 min. While the lowest ash content was recorded banana chips fried without MLP for 1.5 min. The

ash content of the fried banana chips increased with the increased duration of the frying time from 1.5 min to 2.5 min due to the application of heat. Likewise, the ash content of the fried banana chips increased with increased concentration of MLP from 3% to 6%. The finding of this study is consistent with (Pragati *et al.*, 2014; Aida *et al.*, 2016). The result of fiber content ranged from 4.43 g to 12.43 g/100g (Table 1). The highest fiber content was recorded for banana chips fried without MLP for 2.5 minutes. The lowest fiber content was recorded for banana chips fried with 6% MLP fried for 1.5 minutes and 2.5 minutes. The finding of this study is supported by Aderinola (2018), who incorporates moringa powder in the enhanced fiber content of smoothies. Though the carbohydrate level of the banana chips was determined by difference, considerable slight variations were observed (Abioye and Aka, 2015). The carbohydrate content ranged from 57.78 - 67.29 g/100 g (Table 1). Banana chips fried for 1.5 minutes without MLP were highest in carbohydrate content and banana chips fried for 2.5 min without MLP were lowest in carbohydrate level. This might be due to the higher frying time increasing the breakdown of all the components in the banana chips during frying (Oke *et al.*, 2018).

Table 1. Effect of frying time and layering of moringa leaf powder on chemical compositions of banana chips (g/100 g on a dry basis).

Frying time (min)	MLP (%)	MC (g/100g)	Fat (g/100g)	Protein (g/100g)	Ash (g/100g)	Fiber (g/100g)	CHO (g/100g)
1.5	0	7.34±0.26 ^{d}	7.39±0.14 ^{a}	4.76± 0.73^{a}	5.67±0.126 ^{a}	7.63±0.15 ^{d}	67.29± 0.82^{c}
	3	6.26±0.29 ^{c}	6.34±0.16 ^{d}	11.1±0.92 ^{d}	6.46± 0.078^{b}	5.61± 0.13 ^{b}	64.28± 0.96 ^{a}
	6	5.29±0.42 ^{b}	3.34±0.15 ^{b}	13.80± 0.30 ^{e}	8.07±0.074 ^{d}	4.43± 0.07 ^{a}	65.01±0.60 ^{ab}
2.5	0	3.75±0.41 ^{a}	11.70±0.69 ^{f}	3.56±0.34 ^{a}	10.73±0.260 ^{f}	12.43± 0.50 ^{f}	57.78^{d}±0.83
	3	3.63±0.17 ^{a}	7.17±0.36 ^{a}	6.34±0.20 ^{b}	9.21± 0.113 ^{e}	6.56± 0.16 ^{c}	67.07± 0.63 ^{c}
	6	3.35± 0.14 ^{a}	4.98±0.13 ^{c}	8.26±0.37 ^{c}	13.65±0.390 ^{g}	4.84± 0.18 ^{a}	64.90± 0.60 ^{ab}
REF		3.64±0.15 ^{a}	8.60 ± 0.3 ^{e}	3.96±0.56 ^{a}	6.94±0.220 ^{c}	10.80±0.23^{e}	66.07±0.77^{b}
Green Banana *		70.69	0.48	1.03	2.5	10	22.1
MLP**		6	6.2	25.3	11.2	9.3	41.3

Values are mean ± SD of duplicate determinations. Mean values with different superscripts down the column are significantly different (p < 0.05). Where, REF (local chips), LSD = Least Significant Difference.

(Khanvilkar *et al.*, 2016)*; Melesse (2011); and (Raghavendra *et al.*, 2016) **

Effect of frying time and layering of Moringa stenopetala leaf powder on beta carotene of banana chips

The β carotene level of fried banana chips ranged between 29.42 and 93.49 µg/g (Table 2). The beta-carotene content of banana chips fried for banana without MLP for 2.5 minutes and REF was not significantly different (p<0.05). An increased concentration of MLP from 3 to 6% increased beta-carotene content. This is due to the antioxidative properties of moringa (Nadeem *et al.*, 2013). Furthermore, banana chips with different frying times had also a significant effect on beta-carotene content. This study is supported by Demasse *et al.* (2007). β-carotene and vitamin C losses during frying are linked to the behavior of physicochemical parameters during the water/lipids exchange.

Table 2. Effect of frying time and layering of *Moringa stenopetala* leaf powder on beta-carotene of banana chips.

Frying time (min)	MLP (%)	*Beta carotene (µg /g)*
1.5	0	46.13 ± 2.51^{d}
	3	72.68 ± 2.14^{e}
	6	93.49±3.76^{f}
2.5	0	29.42 ± 0.71^{a}
	3	31.27 ± 1.69^{ab}
	6	39.18 ± 2.16^{c}
REF		34.62 ± 2.09^{bc}

Values are mean ± SD of duplicate determinations. Mean values with different superscripts down the column are significantly different (p < 0.05). Where REF (local chips), LSD = Least Significant Difference.

Descriptive sensory analysis of banana chips

The sensory panels generated thirty banana chips quality descriptors and their definition, reference standards and anchors are given (Table 3). The appearance (golden brown), taste (sour, astringent), and after-taste (lingering) attributes were not affected (p<0.05) by the combinations (Table 3. The appearance attribute (green), taste attribute (sour, astringent) and aroma (salty) properties of the banana chips were affected (p<0.05) by the combinations. All attributes of texture by hand texture mouth were significantly affected (p<0.05) by the combination (Table 3). Taste attributes (sour, astringent) and after-taste

(lingering) of the banana chips were not significantly affected ($p<0.05$) by the formulation (Table 3).

The banana chips showed considerable variation in roughness (Table 3). Banana chips of BC3 and BC6 were rougher ($p<0.05$) compared to reference samples REF (locally processed chips) and BC2, BC4 and BC5 had no significant difference in roughness among them. Banana chips of BC4, BC5 and BC6 showed no significant variation in crispness (Table 3). Banana chips of BC4, BC5, and BC6 were crispier ($p<0.05$) compared to REF (locally processed chips). The banana chips showed considerable variation in sweetness (Table 3). Banana chips of BC2, BC3, BC5 and BC6 were not sweeter ($p<0.05$) compared to reference samples REF (locally processed chips) and banana chips of BC1 and BC4 were sweeter ($p<0.05$) compared to REF. Furthermore, BC2, BC3, BC5 and BC6 of banana chips were lower ($p<0.05$) in sweetness than the sample without moringa combinations.

Table 3. Descriptive sensory profile of chips prepared from unripe banana and moringa leaf powder at different times and concentrations.

Sample	Attribute	Chips type						
		BC1	BC2	BC3	BC4	BC5	BC6	REF
Appearance	Rough	1.375^{a}	2.875^{ab}	5.75^{bc}	2.875^{ab}	3.25^{ab}	7.875^{c}	4.85^{abc}
	Yellow	6.120^{b}	2.500^{a}	1.75^{a}	8.120^{b}	2.00^{a}	1.870^{a}	8.00^{b}
	Golden brown	4.250^{a}	2.120^{a}	2.12^{a}	3.000^{a}	5.75^{a}	4.370^{a}	3.28^{a}
	Greasy	1.120^{a}	1.750^{ab}	1.37^{a}	2.620^{ab}	3.12^{ab}	5.000^{b}	4.28^{ab}
	Brown	1.000^{a}	2.750^{abc}	6.50^{c}	2.250^{ab}	5.25^{bc}	6.500^{c}	6.50^{c}
	Green	0.875^{ab}	4.000^{b}	2.25^{ab}	0.500^{a}	1.12^{ab}	2.000^{ab}	1.42^{ab}
Texture by hand	Hard	1.620^{bc}	4.750^{a}	6.12^{a}	0.870^{b}	5.75^{a}	6.620^{a}	6.71^{a}
	Soft	6.250^{bc}	2.120^{a}	8.50^{c}	1.500^{a}	2.17^{a}	3.000^{ab}	4.14^{ab}
	Brittle	4.620^{ab}	2.120^{a}	4.87^{ab}	7.500^{b}	5.37^{ab}	5.250^{ab}	3.57^{a}
	Springy	4.620^{abc}	2.370^{abc}	1.75^{ab}	4.250^{abc}	5.62^{bc}	1.25^{a}	5.85^{c}
Texture by Mouth	Crispy	4.870^{ab}	1.500^{b}	1.25^{b}	8.870^{a}	6.87^{a}	6.370^{a}	5.42^{ab}
	Chewy	7.500^{bc}	5.870^{b}	1.75^{a}	1.120^{a}	3.12^{a}	1.750^{a}	8.42^{c}
	Breakability	7.120^{b}	2.370^{a}	5.87^{ac}	8.370^{b}	5.87^{bc}	1.000^{a}	2.28^{a}
	Dry mouth feel	0.750^{a}	3.870^{bcd}	1.75^{ab}	5.000^{a}	4.87^{bc}	7.750^{e}	2.42^{abc}
	fine particles	1.370^{a}	3.500^{ab}	7.00^{c}	2.000^{a}	5.37^{bc}	7.250^{c}	3.28^{ab}
Aroma	Oily	2.500^{a}	4.370^{abc}	6.50^{bcd}	3.500^{ab}	2.50^{a}	4.000^{abc}	8.00^{d}
	Fried banana	7.120^{b}	4.000^{a}	4.75^{ab}	5.000^{a}	5.75^{ab}	6.620^{b}	3.85^{a}
	Leafy	0.870^{a}	3.250^{ab}	4.62^{bc}	1.250^{a}	3.50^{ab}	6.750^{c}	3.14^{ab}
	Fruity	3.870^{abc}	1.870^{ab}	4.75^{bc}	1.620^{a}	2.87^{ab}	6.370^{c}	3.85^{abc}
	Salty	2.00^{ab}	0.750^{a}	3.12^{b}	1.870^{ab}	2.12^{ab}	1.750^{ab}	3.00^{ab}
Taste	Sour	3.00^{a}	2.000^{a}	2.12^{a}	2.620^{a}	3.00^{a}	1.370^{a}	3.00^{a}
	Starchy	7.500^{b}	3.000^{a}	3.50^{ab}	4.370^{ab}	4.00^{ab}	4.870^{ab}	3.85^{ab}
	Unripe banana	6.620^{c}	0.750^{a}	2.50^{ab}	5.250^{c}	2.37^{ab}	4.750^{bc}	2.28^{ab}
	Sweet	7.370^{de}	2.370^{ab}	3.50^{abc}	8.370^{e}	4.62^{bc}	1.870^{a}	5.85^{cd}
	Astringent	1.370^{a}	1.750^{a}	2.87^{a}	1.000^{a}	4.00^{a}	4.000^{a}	4.57^{a}
	Bitter	0.750^{a}	1.120^{ab}	3.75^{bc}	0.750^{a}	2.75^{abc}	4.000^{c}	1.00^{a}
After taste	Bitter	0.500^{a}	1.500^{abc}	5.12^{d}	1.870^{abc}	2.87^{bc}	3.620^{cd}	0.85^{ab}
	Astringent	1.370^{a}	1.370^{a}	5.00^{b}	0.620^{a}	4.00^{b}	2.870^{ab}	0.85^{a}
	Lingering	3.370^{a}	2.620^{a}	4.25^{a}	3.120^{a}	2.87^{a}	2.870^{a}	1.71^{a}
	Dry mouth feel	2.750^{ab}	1.750^{a}	6.50^{c}	5.250^{abc}	3.00^{abc}	6.000^{bc}	2.57^{ab}

Values are Mean ± standard deviation (n=2). Values in a row with different letters in superscript are significantly different ($p<0.05$.

Conclusion

The protein content of banana chips decreased and the fat and ash content increased with increased frying times from 1.5 to 2.5 minutes. Frying banana chips for 1.5 minutes resulted in higher protein content than banana chips fried for 2.5 minutes. However, the protein and beta-carotene contents of the banana chips increased when the concentration of MLP increased from 3 to 6. The beta-carotene content of banana chips is negatively affected by frying time. The increased concentration of *Moringa stenopetala* leaf powder somehow reduces the losses of beta carotene. While the beta carotene content of banana chips fried for banana with 6% of MLP for 2.5 minutes and REF were similar. Descriptive sensory properties of banana were affected by both frying time and concentration of moringa leaf powder. The 3% MLP banana chips were acceptable for all sensory attributes as opposed to 6% MLP banana chips, thus, it was analyzed for nutritional composition. The results showed that the 3% MLP banana chips had more protein, and less fat content than the control (0% MLP) banana chips. The sensory profiles of banana chips like hardness, roughness, and crispiness, were affected by frying times, which increased from 1.5 minutes to 2.5 minutes. Finally, I conclude that layering of 6% MLP improved protein or decreased the sensory acceptability of banana chips.

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