Effects of Frying time and Layering of Moringa (moringa stenopetala) Leaf powder on Oxidative Stability and total carotenoids content of Banana Chips

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Research Article

Keywords: proximate composition, green banana, frying time, sensory properties, moringa leaf powder

Posted Date: August 4th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10532223/v2

Additional Declarations: The authors declare no competing interests.

Abstract

Banana (Musa-sapientum L) is a typical climacteric fruit that highly cultivated and mostly accepted fruit due to sensorial acceptability and nutritional value. There is no well shelf stabledalue banana products were developed. The aim of this study was to e effects of frying time and layering of Moringa leaf powder on free fatty acid, peroxide value and total carotenoids on banana chips. In this study the two to three levels; moringa leaf powder layers (3% & 6%) and three levels of frying time (1.5, 2, & 2.5 minutes) were combinated. The results showed that the banana chips had free fatty acid (0.19g/100g–1.19g/100g), per oxide value (0.78g/100g–1.79g/100g) and total carotenoid contents (50.59µg /g-373.10 µg /g). The FFA and PV of banana chips were negatively affected by concentration of MLP. On the other hand, the fat content of banana chips resulted higher through frying time due to the replacement of moisture with frying oil. The increased concentration of moringa leaf powder somehow reduces the losses of total carotenoids.The layering of moringa leaf powder during prolonged frying to banana chips for improves oxidative stabilities and without compromising the total carotenoid contents of banana chips

INTRODUCTION

In Ethiopia, dessert banana is the major fruit crop that is 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 banana (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 very limited commercial processing of bananas. Most people consume bananas fresh, steamed or boiled. During bumper harvests, farmers sell bananas at giveaway prices and many go to waste. Processing of banana to chips may add value to this fruit and reduce the wasted banana (Abd *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 study reported by Wani et al., (2017) chips thickness, frying time and frying temperature affected the banana chips quality in deep fat frying. Banana chips have been found to be inferior in protein quality and oxidative stability. It was reported that addition of moringa leaves could improve protein level and anti-oxidative properties of smoothies (in moringa powder based banana beverages) (Taiwo, 2018). However, there is limited study towards the influences addition of moringa stenopetala leaf powder and frying times on nutritional quality, oxidative stability and sensory properties of banana chips with particular focus on banana from Ethiopia. Thus, the aim of this study is to evaluate the analysis of nutritional and sensory characteristics of banana chips as influenced by frying condition

MATERIAL AND METHODS

Materials

Samples (banana, moringa and oil) were collected and secured based on their requirement. Green mature banana (*Musasaptieum*) was collected from Southern Agricultural Research Institute and while moringa stenopetala leaf was received from Arbaminch Agricultural Research Center. Edible oil was purchased from local market, Hawassa, Ethiopia. Banana (*Musasapitium*) samples with similar mass, maturity, and ripening stage was selected and used for the experiment.

Sample Preparations

Moringa stenopetala leaf powder was prepared by distributing leaflets thinly on mash tied on racks in well ventilated room. The leaves were dried within a maximum of 4 days in a loading density of 1 kg/m^2. The dried leaf was milled by mortar the final product was sieved by (0.2 mm) screen size to obtain very fine powder (Sauveur & Bronin, 2006). According to wani et al., (2017) the cleaned 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 in to 2% salt solution to prevent enzymatic browning. All slices were reshaped to the same circular pieces diameter of 4 cm and moringa powder was layered on banana slice. The technique carried out by measuring the weight of slice and 3 and 6% of moringa stenopetala leaf powder. The half of moringa stenopetala leaf powder was uniformly distributed on the circular pieces and the layer was on both sides of the slice; then the slices was dried in an oven dryer at 65°C for 30 minutes.

Frying

The prepared and dried banana slices were deep fried at a temperature of 180ºC in vegetable oil according to(Wanakamol &Poonlarp, 2018) all fried chips were drained for 15 seconds to remove excess oil. Then the fried chips were packed in polyethylene bags and stored in cold place without sunlight until analysis.

Treatments and Experimental Design

The experiment was designed as a full factorial experiment in which the treatments consider all possible combinations of the selected levels. In these experiment two factors (frying time and layering of moringa leaf powder were considered.

Free fatty acid determination

Free fatty acid content, or acid value, reflects the amount of fatty acids hydrolyzed from triacylglycerol's. A 5g banana chips was weighed into a 250- ml Erlenmeyer flask and 100 ml neutralized ethanol was

mixed and 2 ml phenolphthalein was used as indicator and shacked to dissolve the mixture completely. Then titrate with standard base (ca. 0.1 N NaOH), was shacked vigorously until the endpoint was reached. This is indicated by a slight pink color that persists for 30 second. The FFA value of each sample was calculated according to IUPAC, (1987).

Peroxide value determination

Peroxide value (mill equivalents oxygen per kg fat) was determined based upon subjecting potassium iodide at room temperature to the oxidant effect of peroxides. The iodine thus liberated was titrated with sodium thiosulphate as described by (IUPAC, 1987). Approximately 1g of the chips sample was weighed into a 100 mL conical flask and dissolved in with10 mL of the solvent (3/2 mixture glacial acetic acid/chloroform (V/V). Subsequently, 0.2 mL of the potassium iodide saturated solution (14 g KI in 10 mL distilled water) was added to the mixture and stand in the dark for exactly 1 minute. Using 20 mL 1% starch solution as indicator, the mixture was titrated with 0.01 N sodium thiosulphate solution (color: purple › colorless). Simultaneously, the blank test was carried out without fat under the same conditions.

Total carotenoids determinations

The total carotenoid content extraction was carried out according to Imungi and Wabule (1990).

Beta carotene content was determined spectrophotometric ally as described by Muchoki et al. (2007).

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 leaf powder on Free Fatty Acid and Peroxide value of banana chips

Free fatty acids and Peroxide Value are essential quality parameters of frying oil and fried products. Free fatty acids are derived from triacylglycerol by cleavage of ester bonds due to the action of lipase, high temperature, and/or moisture. Thus, high free fatty acids content in the frying oil may cause further oxidation and lead to development of offensive taste and flavor. Free fatty acids content is one of the most important concerns in the refining of edible oil and also in the frying of foods. It is often used to indicate oil quality and its suitability for edibility (Chew & Nyam, 2020). The Peroxide Value is a parameter specifying the content of oxygen as peroxide, especially hydro peroxides in a substance. The Peroxide Value is a measure of the oxidation present. Peroxide values are expressed either in mill

equivalents of peroxide/kg or in mill moles of peroxide/L. Thus, free fatty acids and Peroxide Value of the fried banana chips were analyzed (Table 1).

Table 1
Effect of frying time and layering of moringa leaf powder on free fatty acid and peroxide value of banana chips

Frying time (min)	MLP (%)	FFA(g/100g)	PV(g/100g)
1.5	0	$0.28 \pm .03^{a}$	$1.47 \pm .05^{d}$
	3	$0.25 \pm .04^{a}$	$1.14 \pm .04^{a}$
	6	$0.19 \pm .02^{a}$	$0.78 \pm .04^{b}$
2.5	0	$0.98 \pm .10^{d}$	$1.79 \pm .07^{e}$
	3	$0.55 \pm .07^{bc}$	$1.17 \pm .02^{a}$
	6	$0.46 \pm .03^{b}$	$0.92 \pm .01^{c}$
REF		$0.67 \pm .03^{c}$	$1.63 \pm .04^{f}$

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

Free fatty acids level of fried banana chips varied from 0.19 to 0.98 g/100g (Table 1). Banana chips fried banana without moringa leaf powder for 2.5 minutes had highest level of free fatty acids. While, banana chips fried banana with 6% of moringa leaf powder for 1.5 minutes had lowest in free fatty acids. The banana chips fried without moringa leaf powder, with 3% moringa leaf powder and 6% MLP for 1.5 minutes had similar free fatty acids level. However, free fatty acids of the banana chips decreased linearly with increased concentration of moringa leaf powder from 3 to 6%. On the other hand, frying time had a significant increased the free fatty acids content of the banana chips ($p < 0.05$), due to hydrolysis or cleavage and oxidation of fatty acid double bonds (Aida *et al*., 2016). It is evident that the layering of moringa leaf powder at all levels decreased the formation of free fatty acids with frying time. This study consistent with (Fereidoon, 2005) that reported the addition of moringa leaf powder reduced the free fatty acids level of fried products due to the presence of natural antioxidants in the leaves of morigna.

The peroxide value of fried the banana chips ranged from 0.79 to 1.79g/100g (Table 1). The highest peroxide value was recorded for banana chips fried banana without moringa leaf powder for 2.5 minutes. While, the lowest peroxide value was recorded for Banana chips fried banana with 6% moringa leaf powder for 1.5 minutes. Peroxide values of banana chips fried with 3% moringa leaf powder for 1.5 minutes and 2.5 minutes had similar peroxide value. However, all treatments had lower ($p < 0.05$) peroxide value compared to the REF The peroxide value of the fried banana chips increased with increasing frying duration and decreased with increased in concentration of moringa leaf powder. This result is an indicative of successful and efficient inhibition of oxidation process and improved keeping

quality by moringa leaf powder layering. Furthermore, the peroxide value of the banana chips is a sign of oxidation which directly translates to the buildup and breakdown of oxidation products (Omara and Erisa, 2019).

Effect of frying time and layering of moringa stenopetala leaf powder on total carotenoids of banana chips

The total carotenoids level of fried banana chips ranged considerably between 50.59 and 373.10 µg/g (Table 2). The total carotenoids content of banana chips fried for banana without moringa leaf powder for 2.5 minutes and REF not significantly different ($p < 0.05$). An increased concentration of MLP from 3 to 6% increased total carotenoids content. This is due anti oxidative properties of moringa(Nadeem *et al*.,2013). Furthermore, banana chips with different frying time had also significant effect on total carotenoids content. This study supported with (Demasse *et al*., 2006) total carotenoids and vitamin C losses during frying are link 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 total carotenoids of banana chips.

Frying time (min)	MLP (%)	Total carotenoids (µg /g)
1.5	0	148.39 ± 3.55^{d}
	3	313.44 ± 4.86^{e}
	6	373.10 ± 4.53^{f}
2.5	0	$50.59 \pm 0.83ab^{e}$
	3	54.52 ± 1.53^{a}
	6	112.28 ± 3.22^{c}
REF		81.72 ± 2.43^{b}

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

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was conducted to confirm association of frying time and moringa leaf powder addition with the presumed banana chips quality (free fatty acids, peroxide value and total carotenoids). Principal Component Analysis showed that the banana chips fried with higher level of Principal Component Analysis (BC3 and BC6) were aligned together with (total carotenoids) (Fig. 1).

These banana chips were on the same PC1 quadrant as total carotenoids. It also indicated that the banana chips that was fried from only banana BC1, BC4 and REF (locally processed chips) were negatively associated with total carotenoids. The banana chips fried without moringa leaf powder for 1.5 minutes (BC1) and banana fried with 3% moringa leaf powder for 1.5 minutes (BC2) were aligned together with peroxide value. Moreover, PCA indicated that the banana chips fried without moringa leaf powder, REF (locally processed chips), and BC1 and BC2 were associated with peroxide. However, moringa leaf powder layered banana chips was associated with increased in total carotenoids and decreased in peroxide value content as it it in the opposite to the PC3 quadrant. Peroxide value as it in the opposite to the PC3 quadrant.

Banana chips

BC1 (only banana for 1.5min), BC2 (banana with 3% moringa leaf powder for 1.5min), BC3 (banana with 6% moringa leaf powder for 1.5min), BC4 (only banana for 2.5min) BC5 (banana with 3% moringa leaf powder for 2.5min), BC6(banana with 6% moringa leaf powder for 2.5min), REF(local chips)

Principal Component analysis loading

(free fatty acid value, peroxide value, and total carotenoids)

CONCLUSION AND RECOMMENDATIONS

The amount of total carotenoids content of banana chips negatively affected by frying time. The increased concentration of moringa stenopetala leaf powder somehow reduces the losses of total carotenoids. While, the total carotenoids content of banana chips fried for banana with 6% of MLP for 2.5minutes and REF were similar. The results showed that the 3% MLP banana chips had more protein, and less fat content in comparison to the control (0% MLP) banana chips. The sensory profiles of banana chips like hardness, roughness, and crispiness were affected by frying times increased from 1.5 minutes to 2.5 minutes. Finally, I conclude that layering of 6% MLP improved protein or decreased sensory acceptability of banana chips. Based on this research the following recommendation can be considered are microbiological analysis, minerals, amino acid profiling, other anti-oxidative stability indicators (DPPH scavenging activity, ferric reducing assay power and total antioxidant activity) and cost benefit analysis of moringa leaf powder based banana chips.

Declarations

Conflicts of interest

The author declared that he has no conflict of interest

Figure 1

Principal Component analysis of chemical composition and oxidative stability of banana chips fried at different time and layering of moringa leaf powder.

Banana chips

BC1 (only banana for 1.5min), BC2 (banana with 3% moringa leaf powder for 1.5min), BC3 (banana with 6% moringa leaf powder for 1.5min), BC4 (only banana for 2.5min) BC5 (banana with 3% moringa leaf powder for 2.5min), BC6(banana with 6% moringa leaf powder for 2.5min), REF(local chips)

Principal Component analysis loading

(free fatty acid value, peroxide value, and total carotenoids)

Author contributions

Mr. Mesfin Wolde performed the study design, practical work and writing of the final manuscript. He was also being the corresponding author for the article in publication. Professor Abadi Gebre(lecture and researcher of food science and technology at Hawassa University) participated in critical and timely advice and technical direction through the process.

Acknowledgements

I am grateful to Southern Agricultural Research Institute, Bonga Agricultural Research Center; for providing financial support and opportunity to undergo this study. I immensely thank my major advisor professor Abadi Gebre for his critical direction and timely advice. Finally top gratitude goes for food and nutrition laboratory technical workers of Hawassa University.

References

1. Abd Elmoneim O, Elkhalifa AM 1, Hassan, Maha. E, Abu Zei (2014) Analytical Quality and Acceptability of Baked and Fried Banana Chip.: https://www.researchgate.net/publication/270159192
2. Abioye V, Aka M (2015) Proximate composition and sensory properties of moringa fortified with maize ogi. Nutr Food sci. http://dx.doi.org/10.4172/2155-9600.S12-001
3. Abuye C, Urga K, Ababa A (2003) A compositional study of Moringa Stenopetala leaves. https://doi.org/10.4314/eamj.v80i5.8695. *June*
4. Amare A, Mulualem A, Mebratie J, Haji, Kebede W (2015) Determinants of Postharvest Banana Loss in the Marketing Chain of Central Ethiopia, Deredawa, Ethiopia; journal Vol.37, pp52

5. Asaolu MF, Omotayo FO (2007) Phytochemical, nutritive and anti-nutritive composition of leaves of Moringaoleifera.phytochemistry and pharmacology. III:339–344
6. Bhalerao NM, Patil NM, Badgujar CD, Patil DR (2009) Studies on integrated nutrient management for tissue cultured Grand Naine banana. Indian J Agricultural Res 43:107–112
7. Chandrashekhar,Vasant K (2019) Medicinal and Nutritional Importance of Banana. Acta Sci Agric 35:29–33
8. CSA (Central Statistical Agency of Ethiopia) (2014) Agricultural Sample Survey. Report on Area and Production of Major Crops. Vol I, VII and VIII.Statistical Bulletin 578. Addis Ababa, Ethiopia
9. Demasse MA, Gouado IL, Ejoh AR, Njinkoue JM, Tchouanguep MF (2018) Losses in -carotene and vitamin C due to frying of plantain (Musa paradisiaca) chips: ISSN 1684–5315 © 2007 Academic Journals.
10. Enoch M, Stanslus O, Susan A, Kephas N, Diego N (2018) Postharvest Losses and their Determinants: A Challenge to Creating a Sustainable Cooking Banana Value Chain
11. Ibrahim AM, Shumeta Z, Bekele A (2015) Assessment of Banana Postharvest Handling Practices and Losses in Ethiopia Assessment of Banana Postharvest Handling Practices and Losses in Ethiopia. January
12. Imungi J, Wabule M (1990) Some Chemical Characteristics and availability of Vitamin A and Vitamin C from Kenyan varieties of Papayas (Carica papaya L. Ecol Food Nutr 24(2):115–120
13. Jangrugruangchok S, Bunrathep S, T (2010) Nutrient and mineral content of eleven different samples of moringaoleifera cultivated in Thailand. J Health Res 24:123–127
14. Kader AA, Rolle RS (2004) The role of post-harvest management in assuring the quality and safety of horticultural produce, vol 152. Food & Agriculture Org
15. Karim OR, kayoed RM (2015) Physic chemical properties of siffdough'amala' prepared from yam flour fortified with moringaleaf powder. Food Health Dis 4:48–58
16. Khanvilkar AM, Kamble AB, Ranveer RC, Ghosh JS, Sahoo AK (2016) Effect of frying media and primary packaging material on shelf life of banana chips. Int Food Res J 23(1):284–288
17. Kikulwe EM, Okurut S, Ajambo S, Nowakunda K, Stoian D, Naziri D (2018) Postharvest losses and their determinants: A challenge to creating a sustainable cooking banana value chain in Uganda. Sustainability (Switzerland), 10(7), 1–19. https://doi.org/10.3390/*su10072381*
18. Kitinoja L, Kader AA (2003) Small scale post-harvest handling practices: a manual for horticultural crops, 4th Edition, Post-harvest Technology Research and Information Center, University of California, Davis. USA
19. Melesse A (2011) Comparative assessment on chemical compositions and feeding values of leaves of Moringa stenopetala and Moringa oleifera using in vitro gas production method. 2(2):31–41
20. Muchoki C, Imungi J, Lamuka P (2007) Changes in β-carotene, ascorbic acid and sensory properties in fermented, solar-dried and stored cowpea leaf vegetables. Afr J Food Agric Nutr Dev 7(3):1–20

21. Oke EK, Idowu MA, Sobukola OP, Adeyeye SAO, Akinsola AO (2018) Frying of Food: A Critical Review. J Culin Sci Technol 16(2):107–127. https://doi.org/10.1080/15428052.2017.1333936
22. Oyeyinka AT, Oyeyinka SA (2016) Moringaoleifera as a food fortificant: Recent trends and prospects. JOURNAL OF THE SAUDI. https://doi.org/10.1016/j.jssas.2016.02.002. SOCIETY OF AGRICULTURAL SCIENCES
23. Qwele K, Hugo A, Oyedemi S, Moyo B, Masika P, Muchenje v (2013) Chemical composition fatty acid content anti-oxidant potential of meat from goats supplemented with Moringa. Meat sci 93:455–462
24. Raghavendra HL, Kekuda TRP, Vijayananda BN, Duressa D, Solomon T (2016) Nutritive Composition and Antimicrobial Activity of Moringa stenopetala (Baker f.) Cufod. 10(3):1–9. https://doi.org/10.9734/JAMPS/2016/29987
25. Ruckmani K, Kavimani S, Anandan R, Jaykar B (1998) Effect of Moringaoleifera Lam on paracetamol-induced hepatoxicity. Indian J Pharm Sci 60:33–35
26. Sanibal EAA, Filho JM (2002) Physical, chemical and nutritional oils subjected to the frying process. Food Ingred South Am 18(3):64–71
27. Stenopetala MM, Stevia S, Bertoni R (2020) Antioxidant and Sensory Properties of Herbal Teas Formulated from Dried Moringa (Moringa Stenopetala) and Stevia (Stevia Rebaudiana Bertoni) Leaves. Food Science and Quality Management, February. https://doi.org/10.7176/fsqm/102-01a
28. Taiwo A, A., Nutritional (2018) Antioxidant and Quality Acceptability of Smoothies Supplemented with MoringaoleiferaLeaves
29. Timothy O, Erisa K (2019) Effects of Continuous Deep Fat Frying on the Physical and Chemical Properties of Assorted Brands of Edible Cooking Oils Sold in Metropolitan Kampala. Department of Quality Control, Quality Assurance and Product Development, AgroWays Uganda Limited. Plot 34–60, Kyabazinga Way, P.O. Box 1924, Jinja, Ugand
30. Therdthai PW, Anuvat J, Chatlada K (2007) Optimization of Vacuum Frying Condition for Shallot. Kasetsart J (Natural Science) 41:338–342
31. Van Loon WAM, Visser JE, Linssen JPH, Somsen DJ, Klok J, H., Voragen AGJ (2007) Effect of pre-drying and par-frying conditions on the crispness of French fries. Eur Food Res Technol 225(5–6):929–935. https://doi.org/10.1007/s00217-006-0463-1
32. Wani SA, Sharma V, Kumar P (2017) Effect of processing parameters on quality attributes of fried banana chips. Department of Food Engineering and Technology, SantLongowal Institute of Engineering and Technology. Longowal 148106 (India)
33. Yang R, Chang L, Hsu J, Weng BBC, Palada C, Chadha ML, Levasseur V (2006) Nutritional and Functional Properties of Moringa Leaves – From Germplasm, to Plant, to Food, to Health. 1–9
34. Youryon P, Supapvanich S (2017) Physicochemical quality and antioxidant changes in 'Leb Mue Nang' banana fruit during ripening. Agric Nat Resour 51(1):47–52. https://doi.org/10.1016/j.anres.2015.12.004

35. Zenebe W, Ali M, Derbew B, Zekarias S, Adam B (2015) Assessment of Banana Postharvest Handling Practices and Losses in Ethiopia
36. Ziaiifar AM, Achir N, Courtois F, Trezzani I, &Trystram G (2008) Review of mechanisms conditions and factors involved in the oil uptake phenomenon during the deep fat frying process. Int J Food Sci Technol 43:1410–1423. 10.1111/j.1365-2621.2007.016

Figures

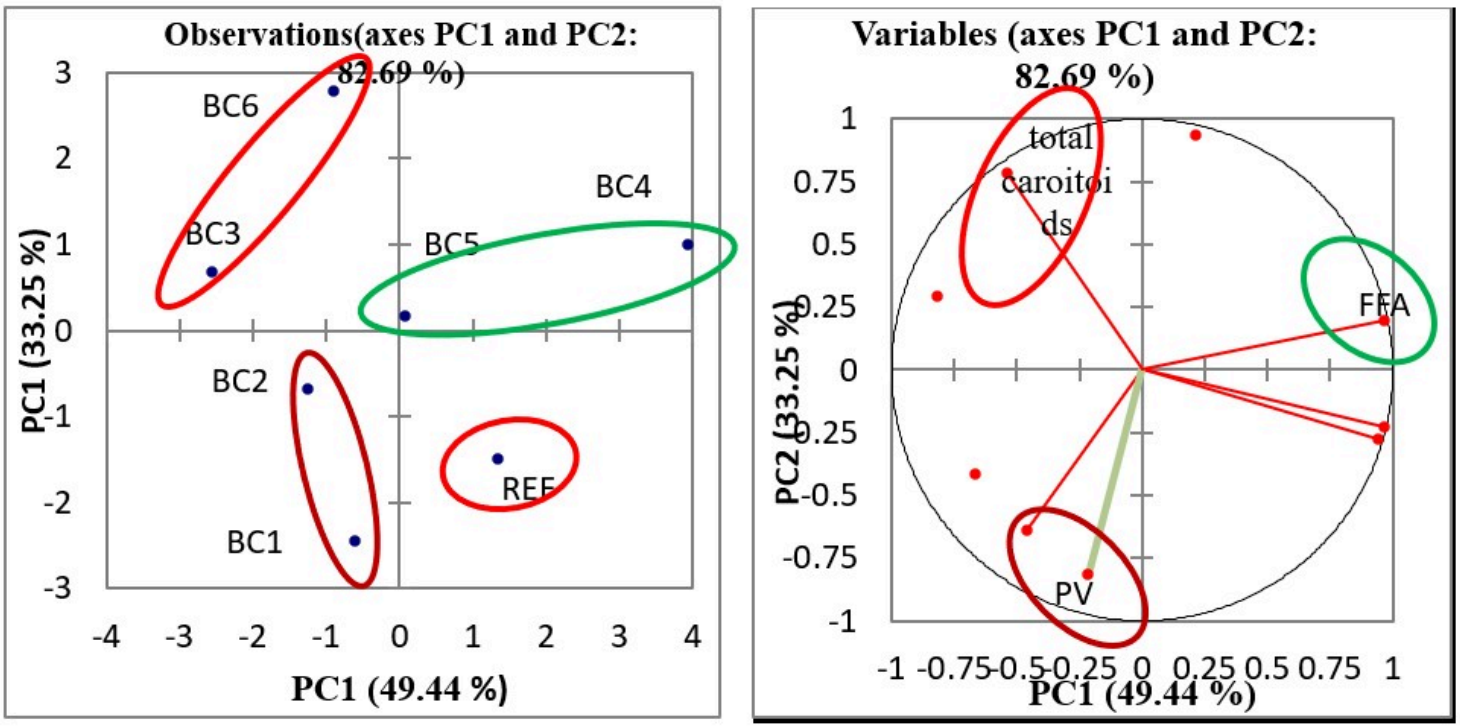

Figure 1

Principal Component analysis of chemical composition and oxidative stability of banana chips fried at different time and layering of moringa leaf powder.

Banana chips: BC1 (only banana for 1.5min), BC2 (banana with 3% moringa leaf powder for 1.5min), BC3 (banana with 6% moringa leaf powder for 1.5min), BC4 (only banana for 2.5min) BC5 (banana with 3% moringa leaf powder for 2.5min), BC6(banana with 6% moringa leaf powder for 2.5min), REF(local chips)

Principal Component analysis loading: (free fatty acid value, peroxide value, and total carotenoids)