Food Research 8 (4) : 384 - 391 (August 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

The utilization of banana peels (*Musa acuminata* Cavendish subgroup) as an alternative ingredient for producing dried plant-based meat products

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Article history:
Received: 16 February 2023
Received in revised form: 13 April 2023
Accepted: 23 May 2024
Available Online: 27 August 2024

Keywords:
Banana peels,
Plant-based meat,
Dried meat product,
Agricultural by-product utilization,
Textured vegetable protein

DOI:
https://doi.org/10.26656/fr.2017.8(4).078

Abstract

The utilization and value-added of agricultural by-products have been highlighted for the novel development of food and non-food products nowadays. This study aimed to produce the dried plant-based meat prototype using banana peels to substitute the textured vegetable protein (TVP) and characterize their properties. Banana peels (state 2 or 3 of maturity) were collected and washed to reduce contamination. The pesticide residues and the characteristics (chemical composition and antioxidant activity) of banana peel were analyzed before use. The meat sample (mixed with ingredients such as TVP, banana peel, sugar, salt, pepper, and other components) was prepared, shaped, and dried in the oven (at 80°C) until the moisture content was lower than 15% and divided for four treatments with different proportions of TVP and peels at the concentrations of 0, 25, 50, and 75 %w/w. The physical and physicochemical properties (color, pH, A_w, texture profile), chemical compositions, biological activity, microbiological test, and sensory evaluation (color, flavor, texture, appearance, and overall liking as well as acceptability) were determined. The results revealed a significantly reduced L^*, a^*, and b^* value (p<0.05) with an increase in banana peels added ratio. The different pH and A_w values were not observed in all treatments (p>0.05). There was no significant difference (p>0.05) was observed in protein content among group treatments compared to the control. The meat sample showed a slightly softer texture when compared to the control (p<0.05). There were no pathogenic microorganisms observed in the meat samples. The overall liking (obtained from 30 panelists) was moderately desirable (5.50 points) from the consumer testing. Moreover, 50% (w/w) of substitution showed the highest score (43.3%), while the control was 33.3% on the acceptability test. According to the results, banana peels could be used as an alternative ingredient for substitute TPV in plant-based meat products. These findings could be helpful for the fundamental data to develop plant-based meat to meet consumer requirements.

1. Introduction

The massive increase in world population is expected from 8 to 10 billion by 2050 and the trend toward the alternative ingredient of organic agricultural by-products which environmentally friendly offers a steady platform for the continuation of food innovation (Godfray *et al.,* 2010; Zaini *et al.,* 2020). Recently, traditional proteins sourced from animals have been a main environmental problem due to huge numbers of livestock. It is affecting water depletion, disrupting the impact on the nutrient cycle, especially phosphorus and nitrogen, contributing to intensifying climate change (Steinfeld *et al.,* 2006). Besides, livestock farming not only directly dramatic impact on the environment but also results in human and animal welfare. Interestingly, the trend of the food industry is growingly focusing on good nutrition that can offer positive health benefits. Consequently, the challenge of alternative food ingredients/sources finding is highlighted by food technologists and establishing novel food products. One of the natural materials which promote the potential for a novel food product such as plant-based meat is a banana peel (*Musa* spp.).

Banana is widely cultivated, especially in tropical areas, and thus contribute to the country’s economy (Zhang *et al.,* 2005). It is famous for fresh fruit consumption due to its acceptable soft texture, great

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eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

aroma, and high level of fiber, as well as the bioactive compounds that generate antioxidant activity (Mohapatra *et al*., 2010; Vu *et al*., 2019). Banana peel is a part of 30-40% of the total fresh fruit weight, and peel is discarded approximately 36 million tons per year (Gomes *et al.,* 2020). Generally, all peels have been made in the organic fertilizer and animal feed industry (Pereira and Maraschin, 2015). Rodriguez *et al.* (2006) and Figuerola *et al.* (2005) reported that fruit fiber has a greater quality than other fiber sources because of lower calorie and phytic acid content, high effectiveness of oil and water holding capacities as well as good colonic ferment ability. According to the National Cancer Standard Institute, banana peel extract is classified as non-toxic to mammalian cells (Someya *et al.,* 2002). Concerning its nutritional quality, the banana peel has become an alternative food ingredient for application in several food items, for instance, bakery products, chapatti, and meat products prototypes (Kurhade *et al.,* 2016; Zhang *et al.,* 2020). Numerous studies have been done on using banana by-products to develop functional food or functional ingredients for health aspects in terms of protein supplementation (Kaur *et al.,* 2014; Martins *et al.,* 2019).

Plant-based food is raising interest because eating meat analogues may help prevent colorectal cancers, heart-related issues, increase bone mass, or lower blood cholesterol (Sadler, 2004; Hu, 2013). Therefore, researchers have expanded their attention to improving and developing meat replacements for innovative food products. The plant-based product market has exponentially escalated because of raised consumer acceptability. Data have illustrated the projected growth of 8.6% in the market snapshot of meat analogs by 2025 with a total market share of USD 21.23 billion (Sadler, 2004). There is no report about using the whole banana peel for application in the meat product. Therefore, the objective of this work was to evaluate the influence of the substitution of banana peel in meat products with the drying method and its nutrient composition, which is used as an alternative ingredient for producing dried plant-based meat products.

2. Materials and methods

2.1 Material and ingredient preparation

The textured vegetable protein (TVP) was purchased from a local company in Pathum Thani province. All ingredients such as salt, sugar, fish sauce, pepper powder (black and white), garlic powder or soy sauce, were purchased from the local supermarket. All the chemical reagent for analysis was used in food grade and purchased from the Sigma Aldrich Company, Bangkok, Thailand.

2.2 Banana peel preparation

The banana peels were received from the King Fruit Company in Pathum Thani province. The peels were removed from the residual pulp until done and washed with sterilized water three times. Then the peels were moved into the salt solution bath for 2% (w/v) to prevent the initial enzymatic browning reaction (10 mins), streamed for 3 mins, and conducted on a tray dryer. The banana peel obtained (moisture content lower than 5%) was packed into the vacuum plastic bag and kept under moisture-free conditions until use. All the raw material was examined for pesticide residuals by using the test kit from the Department of Medical Sciences (DMSC), Thailand, every time and every batch before other processing.

2.3 Dried meat preparation

The TVP was prepared by immersing it in the water until a soft texture, removing the moisture by compressing, and placed in the aluminum pan. The small piece of banana peels was prepared (the size of the meat sample was prepared as 2.0×5.0×0.5 cm.) and divided into four groups for substituting of TVP at ratios of 0, 25, 50, and 75 %(w/w). Then all the material was mixed with other ingredients, all the mixture was mixed well. The mixture obtained was shaped and cut into the small ones, then placed into the tray dryer instrument. The plant-based meat sample was conducted to the drying process for 90 mins at 70°C until dried (the moisture content was lower than 5%). All sample was kept in the zip lock plastic bag with a moisture absorber added before further analysis. For this study, the banana peel at 100% (w/w) use cannot be processed because the texture properties of the final product cannot be shaped.

2.4 Color of peel and meat product measurement

The color of the meat sample was measured by using Color Quest XE (Hunter Lab, Virginia). The color value of the samples was presented as L^*, a^*, b^* (da Silva *et al.,* 2019). The L^* was presented as lightness (1-100) of the product, a^* was red (+) to green (-) color, and b^* was yellow (+) to blue (-) color.

2.5 pH and A_w value determination

The pH of the dried meat sample was measured by using a pH meter (pH 510, Eutech Instrument, Singapore). About 20 g of sample was put into a 50 mL beaker, dissolved with distilled water (20 mL), and mixed until homogeneous sample. The sample was measured with the pH value, and the data was recorded. (da Silva *et al.,* 2019).

The water activity (A_w) of the meat sample was determined using a water activity instrument (Novasina AwC500, Switzerland) under the condition of 25±0.1°C, and then the data was recorded (da Silva *et al.,* 2019).

2.6 Proximate analysis

Moisture, total fat content using the Soxhlet extraction method, the percentage of nitrogen using the Kjeldahl method, and then converse to the crude protein by N × 6.25, and the total ash content of dried meat sample were determined (Association of the Official Analytical Collaboration (AOAC) International, 2000). The carbohydrate content was estimated by subtracting the sum of percentages of moisture, crude fat, crude protein, and ash contents. The carbohydrate content was calculated by the following equation (1):

$$\text{Carbohydrate} = 100\% - \%(\text{moisture} + \text{ash} + \text{crude protein} + \text{fat}) \quad (1)$$

2.7 Texture measurement

The texture properties of dried meat samples were slightly adapted from da Silva *et al.* (2019) and Heck *et al.* (2019). Each meat sample treatment was approximately prepared into a small piece (2.0×4.0 cm). Then, the cutting mode of measurement was performed by texture analyzer instrument (TA-XT plus, Stable Micro Systems, Surrey, UK) at 25°C. The knife-cut probe was used for compressing at 50% of the original height of the sample. Then, the firmness, springiness, cohesiveness, and chewiness were measured. The trial was performed for three replications, and the data was recorded.

2.8 Biological activity test

Total polyphenol content (TP) was determined according to ISO 14502-1:2005 (International Organization for Standardization (ISO), 2005). The meat sample was left for 1 hr and the absorbance at 765 nm was measured. The TP was expressed as gallic acid equivalents (GAE) in mg GAE/g of the sample. The gallic acid was used as the standard curve for the calculation of the amount of TP.

For the DPPH test, the method of Molyneux was used with some modifications (Liu *et al.,* 2017). The dried meat sample was dissolved in distilled water, and the solution obtained (50 µL) was mixed with 1,950 µL of 60 µM of DPPH solutions. Next, the mixtures were left in the dark condition (30 mins) and measured the absorbance at 517 nm. The radical scavenging activity was expressed as µM Trolox equivalent/g of sample.

2.9 Microbiological determination

The microbial properties of the obtained meat sample were analyzed following the protocol described by Serdaroğlu *et al.* (2007) with some modifications. Total plate count, *Escherichia coli*/Coliform, *Staphylococcus aureus*, yeast and mold as well as *Bacillus cereus* were determined. The 3M Petrifilm™ methods were used and referred from the BAM guideline. The 10 g of meat sample was added into a zip-lock plastic bag that contained 90 mL of sterile 0.1% (w/v) buffered peptone water (BPW). After that, the stomacher machine (model 400 Circulator) was applied for good mixing, and appropriate dilutions in 0.1% BPW were poured in duplicate of each 3M Petrifilm™ microorganism's type. The number of microbial was observed and presented as CFU/g.

2.10 Sensory assessment

The sensory evaluation was performed by thirty consumers from Rajamangala University of Technology Thanyaburi. The dried meat samples were cooked and prepared into the sensory cup for one piece of each treatment and labeled with a random number (three digits). The 9-point hedonic scale (1: strong disliking, 5: moderate liking, and 9: strong liking) was used for the meat sample quality assessment (including color, odor, flavor, appearance, firmness, oiliness, juiciness, springiness, and overall liking). Also, the percentage of acceptance was considered and examined. The result was recorded (Oh *et al.,* 2019).

2.11 Statistical analysis

All experiment data were presented as mean±standard deviation (SD). The data was collected by using One-way ANOVA with Duncan's multiple ranges tests. The significant level was 95% by analysis with SPSS software (SPSS 16.0 for Windows, SPSS Inc., Chicago, USA).

3. Results and discussion

3.1 Chemical composition and total phenolic content and DPPH activity of banana peels

All banana peels were determined by their chemical composition. The peel found a fibre content of 19.49±2.76%, following the protein content of 9.56±2.37%, which showed the potential of plant protein sources. This study was similar to previous research by Eshak (2016), which reported that the protein content and fibre content in banana peels (different species) used in flat bread products was 8.74% and 11.20% dry basis, respectively. The fiber also provides a rough texture which may help improve the texture properties (firmness or cohesiveness) of plant-based meat product production. The chemical composition of raw material is shown in Table 1.

https://doi.org/10.26656/fr.2017.8(4).078

Table 1. The chemical composition of banana peels.

Sample	Parameters (% dry basis)					
	Moisture	Ash	Lipid	Protein	Fiber	Carbohydrate*
Banana peels	6.42±0.88	12.73±2.09	5.04±1.65	9.56±2.37	19.49±2.76	46.76±4.00

Values are presented as mean±SD (n = 3).
* Total carbohydrate was calculated by the difference in percentage.

The antioxidative activity of raw material was determined by the total polyphenol content and radical scavenging activity (DPPH), and the result is shown in Table 2. The total polyphenol content in banana peels was 441.25±15.28 mg gallic acid/g sample, and the DPPH activity was 108.91±7.60 µmol Trolox/100 g dry basis. The chemical composition of the dried meat products containing banana peel was presented as a good source of protein. Meanwhile, the total polyphenol content and DPPH activity were directly dependent on the thermal pre-treatment effect. The drying time and temperature may affect the active form of biological substances in the plant. Several studies illustrated that the structure of the phenolic group was not stable at high temperatures (Kim *et al.,* 2011; Thanonkaew *et al.,* 2012). Meanwhile, this study immersed the peels into the salt concentration, contributing to a ratio of solution to solid, playing a vital role in phenolic extraction, and influencing the phenolic content recovery (Meneses *et al.*, 2013). Besides, the lower DPPH antioxidant activity of the banana peels may be caused by the salt media solution effect as well.

Table 2. The antioxidant activity of banana peels.

Sample	Total phenolic content (mg gallic acid/g sample)	DPPH activity (µmol Trolox/g sample)
Banana peels	441.25±15.28	108.91±7.60

Values are presented as mean±SD (n=3).

3.2 Effect of replacement textured vegetable protein by banana peels on physical and physiochemical properties of dried meat samples

The color attributes of dried meat samples supplemented with banana peel are shown in Table 3. The changing color of the food product is the main parameter for food quality that directly affects consumer acceptance. The highest score of lightness (L*) value was observed in the meat sample that supplemented banana peels for 25% (w/w). No significant difference was observed between the control and 25% treatment (p>0.05). Besides, the results showed a significantly lowered redness (a^*) and yellowness (b^*) value of the meat sample when the banana peel ratio increased (p<0.05). The samples obtained with banana peels showed water activity of 0.46-0.58 and a neutral pH of 6.44-6.90 for all treatments (Table 4). For the physical properties in terms of color, the initial peels seem like a dark brown color after passing the thermal treatment, which may decrease the whiteness of the final product. However, these properties could be used as fundamental criteria and concerns for further developing plant-based meat made of banana peels. The meat samples showed a lower water activity and neutral pH value. Based on the results, the replacement of TPV with banana peels has not affected the physicochemical of the final product. It will be useful for the shelf-life investigation of dried meat samples.

3.3 Effect of replacement textured vegetable protein by banana peels on texture properties of dried meat samples

The texture profile of dried meat samples supplemented with banana peels at different ratios is shown in Table 5. The results showed that substituting TVP with banana peels at 25%, but not over 50%, indicated the desirable texture characteristics, particularly the hardness of dried meat samples. Meanwhile, a significant decrease was observed in the springiness and chewiness value of meat products when increasing the amount of banana peel compared to the control (p<0.05). The increase of banana peels in the meat sample made the dried meat sample crack due to lower springiness properties. Generally, the main composition in the peel was fibre, which affected the rough texture of the final product and resulted in lower chewiness and cohesiveness. However, the specific criteria of banana peel stage selection may be considered for peel preparation due to its chemical composition level (soluble or insoluble fibre). For texture characteristic of dried meat products, based on the

Table 3. The color value of the dried meat samples when supplemented with banana peels.

Color	Sample (concentrations; % w/w)			
	0 (control)	25%	50%	75%
L^*	14.18±0.95^a	13.58±1.04^a	11.82±0.69^b	9.55±1.16^c
a^*	5.07±1.07^a	3.74±0.33^c	4.31±0.49^b	3.78±0.21^c
b^*	1.99±0.13^{ab}	2.08±0.21^a	2.09±0.20^a	1.74±0.27^b

Values are presented as mean±SD (n=3). Values with different superscripts within the same row are statistically significantly different at (p<0.05).

https://doi.org/10.26656/fr.2017.8(4).078

Table 4. The pH and A_w value of the dried meat samples when supplemented with banana peels.

Parameters	Sample (concentrations; % w/w)			
	0 (control)	25%	50%	75%
pH	6.90±0.12^a	6.44±0.09^b	6.57±0.06^b	6.48±0.04^b
A_w	0.46±0.04^b	0.50±0.02^b	0.55±0.02^a	0.58±0.03^a

Values are presented as mean±SD (n=3). Values with different superscripts within the same row are statistically significantly different at (p<0.05).

Table 5. Texture profile of dried meat samples supplemented with banana peels at different ratios.

Parameters	Sample (concentrations; % w/w)			
	0 (control)	25%	50%	75%
Hardness (N)	361.30±9.10^a	349.56±9.45^c	353.16±9.44^b	354.16±11.60^b
Springiness (mm)	46.64±3.46^a	41.67±2.11^{ab}	40.01±2.08^b	40.42±3.16^b
Cohesiveness	59.57±1.41^a	63.99±2.50^a	55.81±2.13^b	54.28±0.56^b
Chewiness (N)	226.68±16.45^a	211.37±5.76^b	221.47±2.25^b	217.59±2.49^c

Values are presented as mean±SD (n=3). Values with different superscripts within the same row are statistically significantly different at (p<0.05).

current study, the utilization of banana peel substitution led to a change in the final attribute of the plant-based meat sample, which contributes to the stability loss (solid loss) of the final products and promotes a soft texture after the cooking process. Nevertheless, this kind of meat sample has no animal fat or alternative fat in the formulation. Therefore, the mixture obtained from other ingredients except fat does not have a strong completely homogeneous, resulting in lower firmness of the final product. On the other hand, the previous research by Issara (2022) noted that a high amount of fat in meat products such as sweet sausage had reduced the hardness of the product. Moreover, a similar observation was reported by Serdaroğlu *et al.* (2017) and Cengiz and Gokoglu (2007) in the chicken patties and frankfurter-type sausages.

3.4 Effect of replacement textured vegetable protein by banana peels on microbiological properties of dried meat sample

The consumer safety and prolonged shelf-life of the dried product were determined by identifying pathogenic microorganisms. The meat sample supplemented with banana peel did not find pathogenic microorganisms, and the total microorganisms test was not over the standard of the dried meat sample (Table 6). Food safety is also the main factor related to consumer health. According to the Thai Industrial Standards Institute (TISI), noted that this product category must not detect *E. coli* over 200 CFU/g and yeast and mold over 500 CFU/g (TISI, 2006). Interestingly, the present study found and followed the standard of dried meat products presented in Table 6. Even though the supplementation of banana peel in the meat sample was not observed for pathogen living, the total microorganisms that were contaminated as a total plate count need to be considered and removed from the final product.

3.5 Effect of replacement textured vegetable protein by banana peels on sensory profile and acceptance of dried meat samples

The sensory attributes and consumer acceptability of the final product are shown in Figure 1. There was a clear difference in 75% of the treatment of banana peel supplementation when compared to other group treatments. The 50% group sample showed the highest score of oiliness in the dried meat, firmness, and overall liking point. Moreover, the consumer acceptance test also found that the highest percentage (43.3%) of acceptability was found in 50% supplementation of peels in the meat sample. The taste or desirable attributes of food products are directly influenced by consumer preference. Besides, the increasing acceptance score may contribute to the texture properties of the final product if it provides high firmness properties and no cracks. Food scientists have emphasized the novel food product

Table 6. The microbial assessment of dried meat samples supplemented with banana peels.

Sample	Microorganism's test (CFU/g)				
	Total plate count	*E. coli / Coliform*	*Staphylococcus aureus*	*Bacillus cereus*	Yeast and Mold
Control (0%)	2.0×10^3	ND	ND	ND	ND
25%	2.1×10^3	ND	ND	ND	ND
50%	2.1×10^3	ND	ND	ND	ND
75%	2.2×10^3	ND	ND	ND	ND

ND: Not detected

https://doi.org/10.26656/fr.2017.8(4).078

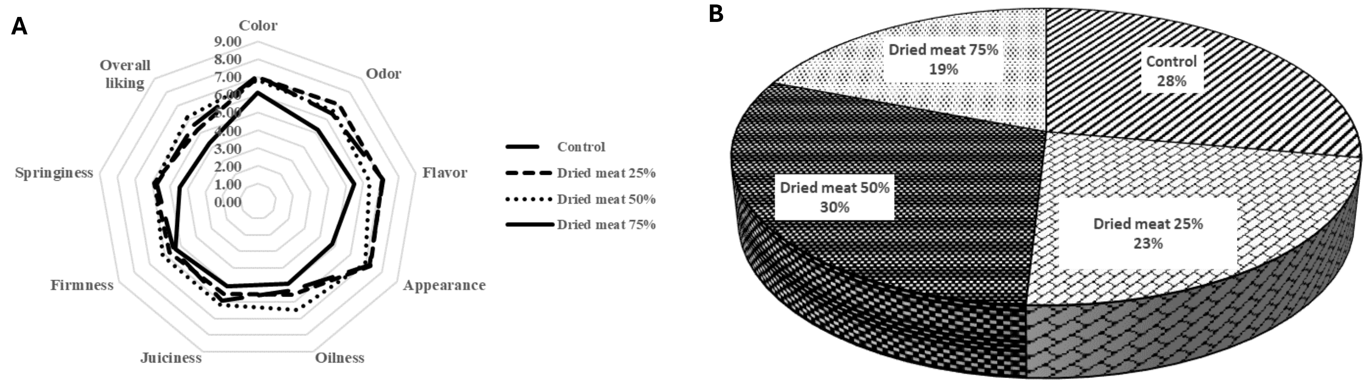

Figure 1. The sensory profile of the dried meat sample supplemented with banana peels (A) and consumer acceptability of the final product (B).

because it may affect consumer acceptance and commercialization. According to the current study, the added peels in plant-based meat help to improve the hardness property and promote the desirable flavor of the dried meat product. These results suggested that banana peel can be used as a bio-ingredient for increasing the natural protein sources or other nutrients in plant-based meat. Also, it promoted the good characteristics of the final meat product by utilizing and replacing the TVP with banana peels ranging from 25-75% (w/w). These data can be used as the preliminary results for developing future plan-based meat made of banana peels to meet consumer requirements.

4. Conclusion

The result of this study suggests that banana peels have the potential for alternative plant protein sources to produce plant-based meat products, especially dried meat form. The banana peel was mainly affected by the texture properties and color of the final product. The substitution of TVP was not over 50% (w/w) by banana peels, resulting in improved meat quality (such as texture, nutritional value, and protein content) and increased consumer acceptance scores. However, the texture properties of the meat prototype of this work need to improve by using the stabilizer agent or other ingredients, and its quality should be further investigated.

Conflict of interests

The authors declare no conflict of interest.

Acknowledgments

This work was supported by the Agricultural Research Development Agency (ARDA), Thailand via the RAINS for Thailand Food Valley Program (Grant number: RAINS64CRP-RAINS64E04). Also, the authors would like to thank the staff of the Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi for helping and guidelines for laboratory instruments.

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