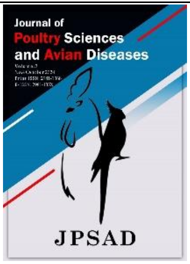
Journal of Poultry Sciences and Avian Diseases

Journal homepage: www.jpsad.com



Nutritional and Qualitative Characteristics of Chicken Patties Incorporated with Green Banana Pulp

Anita Chappalwar[1], Rishav Kumar[1*], Vikas Pathak[1], Arun Verma[2], Vincentraju Rajkumar[2], Meena Goswami[1*]

[1] Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Deen Dayal Upadhyaya Veterinary Science University, Mathura, U.P. India
[2] Division of Goat Products Technology, Central Institute for Research on Goats, Makhdoom, U.P. India

*** Corresponding author email address**: dr.goswami2008@yahoo.co.in, rzk0108@auburn.edu

A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Chappalwar, A., Kumar, R., Pathak, V., Verma, A., Rajkumar, V., & Goswami, M. (2026). Nutritional and Qualitative Characteristics of Chicken Patties Incorporated With Green Banana Pulp. *Journal of Poultry Sciences and Avian Diseases*, *4*(2), 1-12.
http://dx.doi.org/10.61838/kman.jpsad.173

A B S T R A C T

This study aimed to develop functional chicken patties with the incorporation of green banana pulp (GB) as a fiber source separately at 2.0, 4.0, and 6.0% levels, with the replacement of meat accordingly for the maintenance of emulsion formulation. The developed chicken patties were subjected to the analysis of rheological behaviors, proximate composition and mineral content, and textural and sensory parameters. The total dietary fiber content of the GB Powder was 34.30±1.25. The rheological behavior of the emulsion showed higher storage modulus values (G′) than the loss modulus values (G″) in both temperature and frequency sweeps. Emulsion, as well as pH, emulsion stability, protein, fat, cholesterol content, water activity, and zinc content, was decreased; however, ash and total dietary fiber, cooking yield, moisture, manganese, iron, copper, potassium, and phosphorous content of the product increased significantly ($p<0.05$) with the incorporation of green banana pulp powder. All textural parameters increased significantly ($p<0.05$) with an increased level of green banana pulp powder in chicken patties, except fracturability. The lightness (L*) and yellowness (b*) values of patties decreased significantly ($p<0.05$) with an increased level of green banana pulp powder. Flavor, texture, juiciness, mouth coating, meat flavor intensity, and overall acceptability scores of controls and GB1 were comparable; however, they decreased significantly ($p<0.05$) in GB2 and GB3. Therefore, it is concluded that acceptable-quality chicken patties could be developed with the incorporation of 2% green banana pulp powder.

Keywords: *Emulsified meat products, Fiber fortification, Functional ingredients, Green banana pulp powder, Rheology*

Article history:
Received 16 November 2025
Revised 31 December 2025
Accepted 16 February 2026
Published online 22 February 2026

1 Introduction

Poultry remains one of India's most significant and rapidly growing food sectors. As per the latest estimates, the total poultry population in India stands at approximately 851.81 million, comprising around 317.07 million backyard birds and 534.74 million commercial poultry (20th livestock census). Chicken accounts for the overwhelming majority, about 95% of this population, followed by ducks at 4–5%, with the remaining percentage comprising other domesticated species. Annual broiler meat production in India has reached approximately 4.5 to 5 million tons, contributing nearly 51% to the nation's total meat output, which is estimated at 9.8 million tons for the year 2022–23 (Mitra et al., 2024). The poultry sector continues to expand at a steady pace, with broiler meat production growing at an average annual rate of 8–10%, and egg production increasing by about 7–8% annually. Egg production has now reached approximately 138 billion per year, placing India among the top three egg producers globally, while the country ranks fifth in broiler meat production worldwide (Apeda, 2014). The poultry market in India was valued at approximately ₹2,304 billion in 2024 and is projected to grow at a compound annual growth rate of 12.6% through 2033. The sector's growth is driven by several factors, including high returns to producers, improved taste and nutritional value, increasing health consciousness among consumers, affordability, and the absence of religious restrictions on poultry consumption in most parts of the country.

Poultry meat is a cheap, versatile, and healthy food that people will want more of in the future. Processed meats are desirable sources of high-quality protein and vitamins that are essential for normal growth and development. Amongst the variety of chicken meat products, chicken patties exhibit industrial and economic importance, which is mainly affected by the raw material quality and composition (Turhan et al., 2005). Patty is a finely comminuted emulsion-based meat product, which is a mixture of proteins, fat particles, water, salt, and often carbohydrates. Fruits are crucial components of a healthy diet because they contain beneficial nutritional and non-nutrient substances. The World Health Organization (W. H. O., 2003) also suggested that every person should consume at least 400 g (about five portions) of fruits and vegetables per day, due to which the risk of chronic diseases such as diabetes, cardiovascular and gastrointestinal diseases, and some types of cancer can be reduced (W. H. O., 2003). Fruits are rich in vitamins and minerals, fiber, and bioactive compounds. Fruits are abundant in soluble fiber, which enhances the technological quality of products by retaining water and lipids. These fibers are fermented more easily in the colon and contain less phytic acid and fewer calories (Eim et al., 2008). Dietary fiber is the non-digestible portion of carbohydrates that provides a wide range of health and physiological benefits. Dietary fiber plays an important role in the human diet and health (Choi et al., 2008). Consumption of dietary fiber provides a feeling of fullness and promotes healthy laxation, reduces LDL and cholesterol levels as well as obesity, diabetes, and cardiovascular and gastrointestinal disorders (Goswami et al., 2021), and prevents diverticular and coronary heart diseases (Lee et al., 2008). It also improves the technological as well as textural properties of the product during processing.

Banana (*Musa* sp.) is one of the world's most common fruits, cultivated universally and consumed generally as a fresh fruit. It is a very popular fruit because of its low price and high nutritional value. Green bananas seem to be a beneficial source of fiber, essential minerals such as potassium and magnesium, and vitamins (Alkarkhi et al., 2010). Green banana flour is a rich source of fiber and contains 43.2-49.7% fiber (Mohapatra et al., 2010) and is a remarkable source of bioactive compounds (Wang et al., 2017). Dietary fiber is a non-digestible form of carbohydrate and lignin that is neither digested nor absorbed in the small intestine and plays an important role in human health(Choi et al., 2012) . Consumption of dietary fiber provides a feeling of fullness and promotes healthy laxation, reduces LDL and cholesterol levels as well as obesity, diabetes, and cardiovascular and gastrointestinal disorders (Biswas et al., 2011), and prevents diverticular and coronary heart diseases (Lee et al., 2008). It also improves the technological as well as textural properties of the product during processing. Green bananas have hardness and high astringency, due to which their consumption is irregular. However, recently, many researchers assessed the technological properties of green bananas, especially in the form of flour as a functional ingredient; subsequently, this has provoked interest in the consumer market (Sarawong et al., 2014). Green bananas are also classified as a functional food due to their nutritional potential and health benefits (Anyasi et al., 2013). Therefore, this study aimed to develop functional chicken patties for consumers suffering from various lifestyle diseases with the incorporation of green banana pulp as a natural fiber.

2 Material and Methods

2.1 Raw Material Processing figur

The study took place in the Department of Livestock Products Technology at DUVASU in Mathura and in the Goat Products Technology Division at CIRG in Makhdoom. Raw chicken meat of 6-week-old chicken obtained within 1-2 h of slaughter from an authorized retail meat shop in Mathura city, packed in pre-sterilized low-density polyethylene (LDPE) bags, and brought to the laboratory within 20 min. The meat was deboned, and the separable fat and connective tissue were trimmed off. The samples were kept for conditioning in a refrigerator at 4±1°C for 6-8 hrs. and then frozen at -18±2°C until further use. Food-grade refined vegetable oil (FortuneVR), sodium tripolyphosphate (Hi Media Laboratories (P) Ltd, Mumbai), salt, condiments, refined wheat flour, and green bananas were purchased from the local market of Mathura. For the preparation of the spice mix, prepared ingredients in the desired ratio were procured from the local market, dried at 45±2°C for 2 hrs, followed by grinding and sieving through the mesh. The spice mix was stored in pre-sterilized low-density polyethylene bags and used as per the required composition (Table 1). The green bananas were manually peeled, and the pulp was cut into 5 mm slices and immediately rinsed in citric acid solution (1 g/L) for 2 hrs. to prevent enzymatic reaction. Banana slices were washed repeatedly with tap water, and after draining off excess liquid, they were dried in a hot air oven at 35±2°C until a constant moisture content was obtained. After dehydration, the slices were ground (Inalsa Maxie food processor) into fine powder form and stored at a refrigeration temperature of 4±1°C in a pre-sterilized low-density polyethylene bag for further use. All chemicals used in the study were of analytical grade and procured from standard firms like HiMedia Laboratories (P) Ltd, Mumbai. The composition of the spice mix used in this study is presented in Table 1.

Table 1. Composition of spice mix

Serial No.	Spices	Percentage (%)
	Black cardamom (Badielaichi)	5
	Cinnamon (Dalchini)	20
	Turmeric (Haldi)	10
	Clove (Loang)	5
	Red chili	10
	Coriander (Dhania)	20
	Cumin (zeera)	10
	Black pepper (Kalimirch)	10
	Aniseed (Soanf)	10
	Total	100

2.2 Preparation of product

The chicken meat patties were prepared according to the method prescribed by Nayak (2015) with slight modifications. Frozen deboned meat was thawed at refrigeration temperatures overnight. Thawed lean meat was cut into smaller chunks and minced in a meat mincer (Sirmen mincer, MOD-TC 32 R10U.P. INOX, Marsango, Italy) with a 6 mm plate followed by a 4 mm plate. The common salt, vegetable oil, refined wheat flour (maida), lemon albedo, sodium tripolyphosphate, spice mixture, and condiment mix were accurately weighed as per the formulation. Meat emulsion was prepared in a Sirman Bowl Chopper (MOD C 15 2.8G 4.0 HP, Marsango, Italy). For 1.5 minutes, the minced meat was mixed with salt and sodium tripolyphosphate. Water in the form of crushed ice was added, and blending continued for 1 min. The above procedure was followed by the addition of refined vegetable oil and blending for another 1-2 min. Then, the spice mixture, condiments, and other ingredients were added and again mixed for 1.5-2 min to achieve the desired emulsion. Adequate care was taken to maintain a temperature below 18°C by preparing the emulsion in cool hours of the morning, by addition of meat and other ingredients in chilled/partially thawed form, and by addition of crushed ice. About 50 g of emulsion was molded on a steel plate with a circular ring (55 mm diameter and 20 mm height). Vernier calipers determined the height and diameter of the patty. Patties were cooked in a preheated convection oven at 160°C for 15 min, after which they were turned upside down and cooked for another 5 min for adequate doneness and to improve appearance and color. The core temperature was measured by using a probe thermometer (Labware

Scientific, Inc., USA) to ensure proper cooking of patties at 72°C. Cooked patties were cooled to room temperature at 25°C and then packed in pre-sterilized LDPE pouches and finally stored at refrigerated temperature 4±1°C for further analysis. Fiber-fortified chicken patties were prepared with the incorporation of green banana pulp powder at 2.0, 4.0, and 6.0 percent levels. The formulation of the emulsion was maintained by replacing lean meat accordingly. The formulation used for the preparation of control as well as functional chicken patties using four different formulations is given in Table 2.

Table 2. Formulation used for the preparation of chicken patties

Sr.No.	Ingredient	% of mix	% of mix	% of mix	% of mix
Sr.No.	Ingredient	Control	GB1	GB2	GB3
1	Chicken	73.2	71.2	69.2	67.2
2	Refined vegetable oil	4	4	4	4
3	Ice flakes	11	11	11	11
4	Salt	1.5	1.5	1.5	1.5
5	Dry spices mix	2.0	2.0	2.0	2.0
6	Condiments	3.0	3.0	3.0	3.0
7	Refined wheat flour	3.0	3.0	3.0	3.0
8	STPP	0.3	0.3	0.3	0.3
9	Lemon albedo powder	1	1	1	1
10	Green banana pulp powder	0	2	4	6

Control patties – low-fat chicken patties without green banana pulp powder, GB1- low-fat fiber fortified chicken patties incorporated with 2% green banana pulp powder, GB2- low-fat fiber fortified chicken patties incorporated with 4% green banana pulp powder, GB3- low-fat fiber fortified chicken patties incorporated with 6% green banana pulp powder.

2.3 Product Evaluation

2.3.1 Physico-chemical properties

Chicken patties were assessed for various quality parameters as per standard procedures. The pH of chicken patties was evaluated as per the (Troutt et al., 1992) method. The stability of the emulsion was determined by the (Baliga & Madaiah, 1970) method. The cooking yield was calculated as below and expressed in percentage (Murphy et al., 1975). The cooking yield was determined by dividing the cooked patties' weight by the raw patties' weight and expressed as a percentage by multiplying it by 100. A proximate composition, such as moisture, protein, and fat percentage, was evaluated as per the (Association of Official Analytical Chemists,1995. Total cholesterol content and mineral content of chicken patties were determined as per the method of (Zlatkis et al., 1953)

and (Reynolds, 1989) respectively. Total dietary fiber (TDF) was determined by the enzymatic method given by (Aoa, 1970). Water activity of each sample was measured as per the method of (Kumar, Goswami, Pathak, Bharti, et al., 2023) using a water activity meter (AquaLab 3 TE, Inc., Pullman, WA). Moisture retention was determined according to the equation presented (El-Magoli et al., 1996), and fat retention was calculated according to the method given by (Murphy et al., 1975). The color parameters of the chicken patties were measured using a Hunter colorimeter of Color Tech PCMþ (Color Tec Associates Inc., Clinton, NJ, USA). The coin-shaped lance of the instrument attached to the software was directly put on the surface of functional chicken patties at six randomly chosen different points, Hunter and Harold (1987). CIE *L**, *a**, and *b** values were determined as indicators of lightness, redness, and yellowness, respectively.

2.3.2 Textural Profile Analysis

The texture profile analysis was done with the help of an instrumental texture profile analyzer (TA HD Plus Texture Analyzer) at the Department of Livestock Products Technology, DUVASU, Mathura. The procedure used for instrumental texture profile analysis was similar to that described by (Bourne, 1978). The Texture Profile Analyzer (TPA) instrument was attached to the software, Texture Expert. Chilled samples were tempered to bring them to room temperature (27ºC). Uniform-sized pieces (1.5×1.5×1.5 cm) were used as the test samples. They were placed on platforms on a fixture and compressed to 75% of their original height at a crosshead speed of 5 mm/s through a two-cycle sequence, using a 25 kg load cell. The parameters determined were: The following parameters were determined *viz.*, Hardness (N/cm2)=maximum force required to compress the sample (H); Springiness (cm/mm)=ability of sample to recover its original form after a deforming force was removed (S); Cohesiveness (Ratio)=Extent to which samples could be deformed before rupture (A2/A1, A1 being the total energy required for first compression and A2 the total energy required for second compression); Gumminess (N/cm2 or g/mm2)=force necessary to disintegrate a semi-solid sample for swallowing (H × Cohesiveness); and Chewiness (N/cm2 or g/mm2) = work required for the sample for swallowing (S × Gumminess).

2.3.3 Rheological Study

The steady rheological properties of chicken meat emulsion were determined using a rotational rheometer (MCR 72, Anton Paar GmbH, Austria) equipped with a parallel plate system (75 mm diameter). The control emulsion, labeled as C in the treatment design, was used as the control. Rotational mode was applied to study the time-dependent flow behavior of the emulsion. To minimize moisture loss during measurement, samples were carefully covered with a thin layer of silicone oil. Flow curves were obtained after a stabilization period of 5 min at 25°C, across shear rates ranging from 1 to 1000 s^{-1}, and apparent viscosity was recorded as a function of shear rate. Before measurement, samples were equilibrated for 90 s. Rheological models were fitted using the original flow behavior software of the Anton Paar Rheometer. All measurements were conducted at 25°C in triplicate.

2.3.4 Mineral Profile analysis

The Mineral composition of chicken meat patties was determined according to the procedure of (Aoa, 1970) with slight modifications. A homogenized sample weighing about 1 g was digested with 15 mL of a perchloric acid and nitric acid mixture (1:4, v/v) while being gently heated until a clear solution was formed. After cooling, the digest was diluted to 100 mL with triple-distilled water and filtered through Whatman No. 40 filter paper. The mineral content of the filtrates was quantified using an Atomic Absorption Spectrophotometer (AA-6880, Shimadzu Corp., Japan) and an Inductively Coupled Plasma Mass Spectrometer (Agilent 5800 ICP-OES). At the same time, potassium concentration was determined separately using a Flame Photometer. Stock solutions of trace minerals (1000 µg/mL) were prepared in double-distilled water and diluted to yield working standards between 1 and 25 ppm for calibration of Co, Cr, Cu, Fe, K, Mn, Na, Zn, Ca, and Mg. Instrumental parameters were set according to recommended wavelengths, namely Co (267.716 nm), Cu (327.395 nm), Fe (238.204 nm), K (766.491 nm), Mn (257.610 nm), Ca (422.67 nm), Na (589.592 nm), Zn (213.857 nm), and Mg (248.33 nm), using hollow cathode lamps and an air–acetylene flame. Phosphorus concentration was determined separately using a UV–Visible spectrophotometer. For this, a 30 mL aliquot of the digested sample was mixed with 10 mL of vanadate–molybdate reagent in a volumetric flask, incubated for 10 min, and the absorbance was measured at 420 nm against a reagent blank. A standard curve was generated using 0.50–2.50 mL of a 100 mg phosphorus standard solution. The phosphorus content of the samples was calculated using the standard curve according to the following formula:

Phosphorus content (%)= A × V/ W ×1000*100

where *A* is the phosphorus concentration (µg) derived from the calibration curve, *V* is the volume (mL), and W is the weight of the sample (g)of the test digest used for color development. All mineral analyses were carried out in triplicate, and results were expressed as Mean±Standard Error (SE).

2.3.5 Sensory evaluation

Sensory evaluation was carried out using the eight-point hedonic scale with 8=extremely desirable and 1=extremely poor (Keeton, 1983). A sensory panel (semi-trained) of seven judges drawn from postgraduate students and faculty members of Veterinary College, DUVASU, Mathura, was requested to evaluate the product for different quality attributes, namely, color and appearance, flavor, texture, juiciness, saltiness, mouth coating, meat flavor intensity, and overall acceptability. Freshly cooked chicken patties were served for sensory evaluation at around 40°C in the sensory evaluation room in the late afternoon, around 4:00 p.m. Sensory panelists were not allowed to communicate with each other, and plain lukewarm water was given for mouth rinsing in between sensing two samples. A total of three replications were carried out. Each analysis was done in duplicate (n=6), except for sensory studies, where seven sensory panelists did sensory evaluations three times, and n=21 observations were recorded for each sensory attribute.

2.4 Statistical analysis

The data obtained in the study for texture profile analysis were statistically analyzed on the “SPSS-16.0” software package for one-way ANOVA as per the standard method. Duplicate samples were drawn for each parameter, and the experiment was replicated thrice (n=6). Data was subjected to one-way analysis of variance and homogeneity tests, and means were compared by using (Duncan et al., 1998) multiple range tests to find the effects between samples.

3 Result and Discussion

3.1 Rheology of chicken emulsion

Figure 1. presents the temperature sweep presents the temperature sweep results of chicken emulsions with different levels of green banana pulp, illustrating the variation in viscoelastic properties as the temperature increases. The addition of green banana pulp powder affected the behavior of chicken emulsion by showing different trends during the heating cycle as well as frequency. The frequency sweep results of chicken emulsions incorporated with different levels of green banana pulp are shown in Figure 2., depicting the influence of green banana pulp concentration on the storage (G′) and loss (G″) moduli across the applied frequency range. Higher G′ modulus than G″ modulus in both temperature and frequency sweeps, which was due to the elastic property of emulsions. The heating cycle indicated a gradual increase in G′ and G″ modulus at 20 to 54°C in GB1, 20 to 45°C in GB2, 20 to 48°C in GB3, and 20 to 45°C for control (C) emulsions; however, thereafter (up to 90°C), both moduli increased speedily. An increase in the modulus at 45-55°C indicates the initial stages of gel network formation due to partial unfolding of myosin (Sano et al., 1988). Thereafter, the myosin rod was completely denatured at 63°C and participated in gel network formation. High starch content in the banana peel also interferes with emulsion structure, which might contribute to the weak gel properties of the emulsion. (Sánchez-González et al., 2009) reported that the addition of wheat dietary fiber in surimi acts as an active dehydrating agent with a change in the environment to hydrophobic side chains, due to which the solvent gets exposed more upon heating and might lead to nonspecific coagulation effortlessly. This effect leads to a continuous, compact, and dense homogeneous structure of the emulsion. The weak gel property of the treated emulsion in the frequency sweep might be due to the greater compactness of the emulsion, which results from the higher water binding capacity. (Correa et al., 2018)observed an increase in modulus following constant behavior on the addition of different concentrations of cassava starch and pea fiber in fermented meat emulsions, indicating a semisolid phenomenon during the entire frequency range. (Flores et al., 2007) reported that the addition of caseinate in meat paste showed a stronger gel structure, as the starch contributed a certain degree of stability to the system.

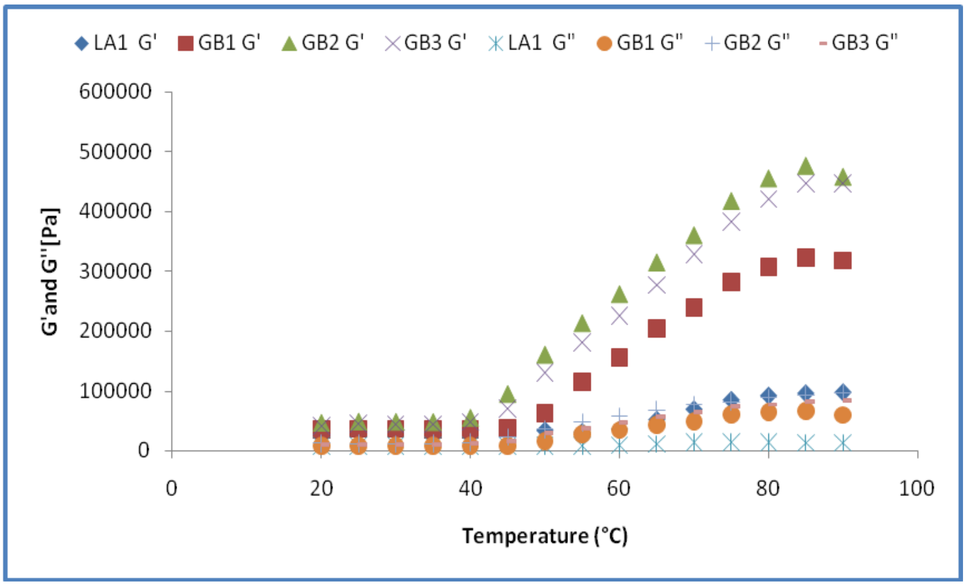


Figure1: Variation of storage modulus (G′) and loss modulus (G″) with temperature for chicken emulsions incorporated with different levels of green banana pulp powder.

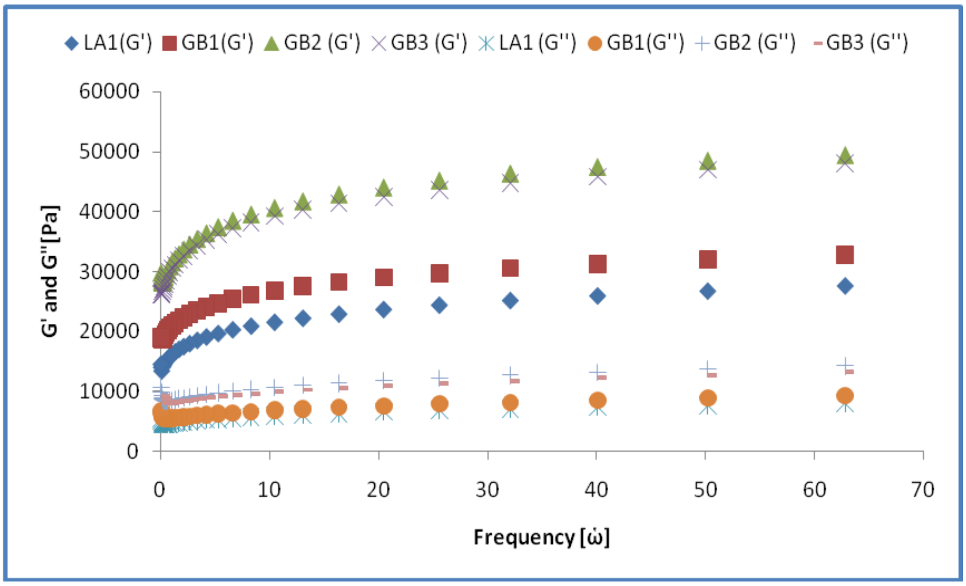


Figure2: Frequency sweep of chicken emulsions incorporated with different levels of green banana pulp powder, showing the variation of storage modulus (G′) and loss modulus (G″) across the tested frequency range.

3.2 Physico-chemical properties

The physico-chemical properties of functional chicken patties incorporated with different levels of green banana pulp powder are presented in Table 3. The emulsion pH and product pH decreased significantly ($p<0.05$) with higher levels of green banana pulp powder, which is attributed to the lower pH of bananas compared to lean meat and the effects of cooking (Sarode and Tayade, 2009). Emulsion stability of the product was comparable up to 4% of green banana pulp incorporation, but decreased significantly ($p<0.05$) in GB3 due to the addition of fiber at a higher level. Cooking yield and moisture content were significantly higher in all GB treatments compared to the control; however, there were no significant differences among GB1, GB2, and GB3. Higher cooking yield and moisture content in treatments might be attributed to an increase in the viscosity of the product by the incorporation of fiber, which ultimately reduced shrinkage in cooking (Lai et al., 2003; Lee et al., 2008). (Kumar et al., 2013; Kumar et al., 2015) also observed an increase in the cooking yield of green banana pulp and soybean hull flour-treated meat patties compared to the control. Results are also in agreement with (Bastos et al., 2014), who observed an increase in yield and water-holding capacity of beef burgers on the addition of banana peel and pulp flour. Fat and cholesterol content decreased significantly ($p<0.05$) with increased levels of green banana pulp powder, which might be due to the replacement of lean meat with fiber having less fat and no cholesterol content (Kumar et al., 2024). Protein content decreased significantly ($p<0.05$) in GB3, but the protein content of GB1 and GB2 was comparable to that of the control (C). Ash and total dietary fiber content of patties increased significantly ($p<0.05$) with the incorporation of green banana pulp powder due to higher mineral and fiber content in banana flour as compared to lean meat. This might be due to the difference in the composition of banana flour, i.e., moisture 4.8±0.04%, fat 1.015±0.04%, protein 1.542±0.06%, fiber 6.1±0.03%, andash 2.16±0.08%, i.e., high fiber and ash content and low fat and protein content. It is free from cholesterol (Gannoruwa, 2008), compared to lean meat, which is replaced with fiber (Kumar, Goswami, Pathak, & Verma, 2023). These results are also in agreement with(Kumar et al., 2015), who also observed a significant ($p<0.05$) decrease in protein, fat, and cholesterol content along with a significant ($p<0.05$) increase in moisture, ash content, crude fiber content, and cooking yield value with an increased level of dried carrot powder in chicken cutlets. Water activity of patties decreased significantly ($p<0.05$) with the incorporation of green banana pulp powder due to the higher water-binding capacity of banana flour, which increased bound water content in the product, making it unavailable for the growth of microorganisms. (Bastos et al., 2014) also observed an increase in yield and water-holding capacity of beef burgers on the addition of banana peel and pulp flour. There was no significant difference between control and treatments for fat retention as well as moisture retention values; however, values increased slightly in treatments compared to control. This might be due to the water and fat holding capacity of natural fibers (Garcıa et al., 2002). This might also be explained as the high total starch content in the banana products gelatinized at high temperatures and absorbed water into starch granules with concomitant swelling (Rodríguez-Ambriz et al., 2008)

Table 3. Physico-chemical properties (Mean±SE) of functional chicken patties incorporated with different levels of green banana pulp powder

Parameter	C	GB1	GB2	GB3
Emulsion pH	5.61^{a}±0.03	5.55^{b}±0.04	5.43^{c}±0.05	5.29^{d}±0.02
Emulsion stability (%)	94.91^{a}±0.65	94.57^{ab}±0.46	94.02^{ab}±0.56	93.16^{b}±0.45
Cooking yield (%)	91.28^{b}±0.40	92.36^{a}±0.37	92.44^{a}±0.31	92.61^{a}±0.39
Product pH	6.05^{a}±0.01	5.83^{b}±0.02	5.62^{c}±0.01	5.41^{d}±0.13
Moisture (%)	67.57b±0.32	68.81^{a}±0.39	69.43^{a}±0.26	69.65^{a}±0.55
Fat (%)	4.70^{a}±0.05	4.10^{b}±0.13	3.80b^{c}±0.11	3.54^{c}±0.17
Protein (%)	19.27^{a}±0.61	18.21^{ab}±0.43	17.76^{ab}±0.57	17.46^{b}±0.48
Ash (%)	2.64^{c}±0.10	2.92^{bc}±0.18	3.21^{ab}±0.07	3.53^{a}±0.07
Cholesterol (mg/100mg)	77.96^{a}±1.09	68.12^{b}±1.15	65.92^{bc}±0.68	63.17^{c}±1.66
TDF (%)	0.34^{d}±0.01	1.56^{c}±0.07	2.18^{b}±0.02	3.17^{a}±0.03
Fat retention (%)	90.27±0.91	90.86±0.51	91.22±0.73	91.50±0.32
Water activity	0.99^{a}±0.00	0.95^{b}±0.00	0.96^{b}±0.02	0.96^{b}±0.00

Moisture retention(%)	62.30±0.39	62.97±0.31	63.09±0.35	63.17±0.25

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly (p<0.05)

3.3 *Mineral profile analysis*

The mineral profile of functional chicken patties incorporated with different levels of green banana pulp powder is presented in Table 4. The manganese, iron, copper, potassium, and phosphorus content of the product increased significantly (p<0.05); however, the zinc content decreased significantly (p<0.05) with the incorporation of green banana pulp powder. Higher potassium and phosphorus content of treatments than control might be due to higher potassium and phosphorus content of the banana, as reported by (Gannoruwa, 2008). (Emaga et al., 2007) also reported that potassium is present in abundance in bananas, followed by magnesium, calcium, and phosphorus content.

Table 4. Mineral profile analysis (Mean±SE) of functional chicken patties incorporated with different levels of green banana pulp powder

Mineral (mg/100mg)	C	GB1	GB2	GB3	Treatment mean
Manganese	0.05^{c}±0.00	0.05b^{c}±0.00	0.06^{b}±0.00	0.07^{a}±0.00	0.06±0.00
Iron	0.13^{b}±0.00	0.14^{b}±0.00	0.15^{a}±0.00	0.16^{a}±0.00	0.14±0.00
Copper	0.44^{b}±0.01	0.46^{b}±0.00	0.66^{a}±0.02	0.71^{a}±0.09	0.57±0.03
Zinc	0.44^{a}±0.04	0.26^{b}±0.02	0.24^{b}±0.01	0.24^{b}±0.00	0.30±0.02
Potassium	317.90^{c}±0.94	433.56^{b}±0.56	449.25^{ab}±0.68	514.92^{a}±0.56	428.91±0.39
Phosphorus	66.62^{d}±1.16	76.56^{c}±1.96	81.19^{b}±1.07	89.85^{a}±0.81	78.55±1.85

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly (p<0.05)

3.4 *Texture profile analysis*

The texture profile analysis of functional chicken patties incorporated with different levels of green banana pulp powder is presented in Table 5. All textural parameters increased significantly (p<0.05) with an increased level of green banana pulp powder in chicken patties, except fracturability. Higher textural parameter values in treatments might be due to the water-binding properties of starch present in banana pulp. (Choi et al., 2012) also observed significantly (p<0.05) higher hardness values in chicken frankfurter sausages containing pumpkin fiber than in the control. Similar results for hardness were also recorded by (Eim et al., 2008) on the addition of carrot dietary fiber over 3% in dry fermented sausage. (Erdem & Alici, 2023) also observed a significant (p<0.05) increase in hardness, springiness, and adhesiveness values in oat flour-treated chicken nuggets. In the present study, results are also in agreement with (Femenia et al., 1997), who observed consistently increased textural properties of model foods supplemented with cauliflower fiber after cooking. However, (Garcıa et al., 2002) observed less adhesiveness and springiness with no change in gumminess and chewiness values of cereal and fruit fibers added to low-fat dry fermented sausages.

Table 5. Texture profile analysis (Mean±SE) of functional chicken patties incorporated with different levels of green banana pulp powder

Parameter	C	GB1	GB2	GB3	Treatment means
Hardness (N/cm2)	31.47^{b}±1.33	42.58^{b}±1.88	49.19^{a}±4.33	49.26^{a}±4.06	44.44±2.15
Fracturability (Ns)	0.11±0.00	0.13±0.00	0.13±0.00	0.12±0.01	0.12±0.00
Springiness (cm)	0.40^{c}±0.02	0.51^{b}±0.01	0.72^{a}±0.03	0.73^{a}±0.01	0.66±0.02
Cohesiveness (ratio)	0.20^{b}±0.01	0.21^{b}±0.00	0.29^{a}±0.00	0.31^{a}±0.01	0.25±0.01
Gumminess(N/cm2)	6.46^{c}±0.45	8.78^{b}±0.99	12.78^{a}±2.27	14.52^{a}±1.54	10.63±1.10
Chewiness	2.63^{c}±0.30	5.48^{b}±0.52	10.52^{a}±1.15	10.89^{a}±0.86	7.38±0.92
Resilience	0.04^{c}±0.00	0.05^{b}±0.00	0.08^{a}±0.00	0.08^{a}±0.00	0.07±0.00

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly (p<0.05)

3.5 Instrumental color analysis

The instrumental color values of chicken patties incorporated with different levels of green banana pulp powder are shown in Table 6. The lightness (L*) and yellowness (B*) values of patties decreased significantly ($p<0.05$) with an increased level of green banana pulp powder. There was no significant difference in redness *(a*)* values between control and treatments; however, redness *a** values increased slightly with increased levels of green banana pulp powder. The possible reason behind these observations might be the enzymatic oxidation of banana pulp by polyphenol oxidase enzyme during drying, which gave a dark color to green banana pulp powder and the product as well. (Kumar et al., 2013) also reported the higher *b** values in chicken nuggets incorporated with 5% added green banana flour.

Table 6. Instrumental color values (Mean±SE) of chicken patties incorporated with different levels of green banana pulp powder

Parameter	C	GB1	GB2	GB3	Treatment means
Lightness *(L*)*	47.29^{a}±2.43	43.62^{ab}±0.37	43.11^{b}±0.31	43.02^{b}±0.32	44.26±0.69
Redness *(a*)*	7.59±0.80	7.82±0.46	7.98±0.27	8.04±0.24	7.86±0.23
Yellowness *(b*)*	15.77^{a}±0.73	8.27^{ab}±0.14	8.18^{b}±0.09	7.77^{b}±0.13	10.00±0.71

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly ($p<0.05$)

3.6 Sensory evaluation

The sensory evaluation scores of functional chicken patties incorporated with different levels of green banana pulp powder are presented in Table 7. The color and appearance scores of GB2 and GB3 decreased significantly ($p<0.05$) compared to control (C) due to the dark color of the banana pulp powder, which was caused by enzymatic oxidation. However, scores of GB1 were comparable to the control (C). There was no significant difference between control and treatments in saltiness. Flavor, texture, juiciness, mouth coating, meat flavor intensity, and overall acceptability scores of control (C) and GB1 were comparable; however, they decreased significantly ($p<0.05$) in GB2 and GB3. Lower acceptability of patties at higher levels of green banana pulp powder incorporation might be due to masking of meat flavor, hard texture, and lower juiciness in the product, which was not liked by sensory panelists. (Bastos et al., 2014) reported that beef burgers with the incorporation of 3% green banana peel and pulp flour were acceptable. (Kumar et al., 2015) recorded the highest sensory scores in chicken nuggets incorporated with 4% green banana flour and 4% soybean hull flour. In the present study, there was no significant difference between control (C) and GB1 for any sensory attribute.

Table 7. Sensory evaluation (Mean±SE) of functional chicken patties incorporated with different levels of green banana pulp powder

Attribute	C	GB1	GB2	GB3	Treatment mean
Color and appearance	7.18^{a}±0.04	7.08^{ab}±0.04	6.95^{b}±0.05	6.80^{c}±0.04	7.00±0.02
Flavor	7.19^{a}±0.03	7.15^{a}±0.02	6.97^{b}±0.03	6.81^{c}±0.04	7.03±0.02
Texture	7.16^{a}±0.02	7.12^{a}±0.03	6.99^{b}±0.04	6.85^{c}±0.04	7.03±0.02
Juiciness	7.12^{a}±0.02	7.08^{a}±0.03	6.95^{b}±0.05	6.74^{c}±0.02	6.97±0.02
Saltiness	7.08±0.02	7.03±0.03	7.02±0.03	6.99±0.04	7.03±0.01
Mouth coating	6.99^{a}±0.03	6.96^{a}±0.03	6.87^{b}±0.03	6.71^{c}±0.03	6.88±0.02
Meat flavor intensity	7.12^{a}±0.02	7.10^{a}±0.02	6.92^{b}±0.05	6.83^{b}±0.03	6.99±0.02
Overall acceptability	7.13^{a}±0.03	7.07^{a}±0.04	6.96^{b}±0.03	6.90^{b}±0.02	7.02±0.01

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly ($p<0.05$)

Sensory attributes were evaluated using an 8-point hedonic scale, where 1 represents ‘extremely undesirable,’ and 8 represents ‘extremely desirable.

4 Conclusion

Incorporation of green banana pulp significantly increased fiber content, cooking yield, ash content, and total dietary fiber percentage, while significantly decreasing fat and cholesterol levels. Replacement of lean meat with green banana pulp powder had no adverse effect on instrumental texture and color parameters. Emulsion and product pH, emulsion stability, fat, protein, cholesterol, and water activity decreased significantly with increasing levels of green banana pulp. In contrast, cooking yield, moisture content, ash content, total dietary fiber (TDF), fat retention, and moisture retention showed a significant increase in the fortified patties compared to the control (C). These results indicate that green banana pulp not only enhances the dietary fiber content of chicken patties but also improves cooking performance and water-holding capacity while reducing fat and cholesterol levels. All mineral content and textural parameters increased significantly (p<0.05) on incorporation of green banana pulp, except zinc content and fracturability values. All color values and sensory scores decreased significantly (p<0.05) in GB2 and GB3 except for redness and saltiness. Therefore, GB1—low-fat, fiber-fortified chicken patties incorporated with 2.0% green banana pulp powder was selected as the best treatment. These promising findings pave the way for further research to evaluate the in vivo effects of incorporating green banana pulp into chicken patties, highlighting its potential as a functional ingredient. Furthermore, this study supports the utilization of green banana pulp, an underused and readily available resource with valuable bioactive properties, as a strategy to enhance product quality while reducing food waste and production costs.

Acknowledgements

The authors wish to express their gratitude to the staff of the Dept of GPT, Central Institute of Research on Goats (CIRG), Makhdoom (U.P.), for their constant help and for making laboratory facilities available for the completion of research work.

Conflict of Interest

We declare that no conflict of interest.

Author Contributions

A.C., R.K., V.P., A.K.V., V.R., and M.G. jointly designed and conceptualized the study. All authors contributed equally to experiment planning, sample preparation, data collection, and laboratory analyses. A.C., R.K., V.P., A.K.V., V.R., and M.G. participated equally in data processing, statistical analysis, and interpretation of the results. The manuscript was written collaboratively by all authors, with each author providing substantial input, revisions, and final approval of the submitted version.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Ethical Considerations

No ethical approval was required for this study, as it did not involve the use of live animals or any procedures causing harm, pain, or distress to experimental animals. The research was conducted using commercially sourced chicken meat obtained from an authorized retail outlet, and no animal experimentation was performed.

Funding

This research received no external funding. No sponsors were involved in the study design, data collection, analysis, interpretation of the results, manuscript preparation, or the decision to submit the article for publication.

References

Alkarkhi, A. F., Saifullah, R., Yong YeohShin, Y. Y., & Azhar Mat Easa, A. M. E. (2010). Physicochemical properties of banana peel flour as influenced by variety and stage of ripeness: multivariate statistical analysis. [URL].

Anyasi, T. A., Jideani, A. I., & McHau, G. R. (2013). Functional properties and postharvest utilization of commercial and noncommercial banana cultivars. Comprehensive Reviews in Food Science and Food Safety, 12(5), 509-522. [PMID: 33412666] [DOI].

Aoa. (1970). Association of official analytical chemistry. Methods of analysis. Washington DC. [URL].

Apeda. (2014). Agricultural and processed food products export development authority. India New Delhi. [URL].

Baliga, B., & Madaiah, N. (1970). Quality of sausage emulsion prepared from mutton. Journal of Food Science, 35(4), 383-385. [DOI].

Bastos, S. C., Pimenta, M. E. S., Pimenta, C. J., Reis, T. A., Nunes, C. A., Pinheiro, A. C. M., & et al. (2014). Alternative fat substitutes for beef burger: technological and sensory characteristics. Journal of Food Science and Technology, 51(9), 2046-2053. [PMID: 25190862] [PMCID: PMC4152509] [PMCID: PMC4152509] [DOI].

Biswas, A., Kumar, V., Bhosle, S., Sahoo, J., & Chatli, M. (2011). Dietary fibers as functional ingredients in meat products and their role in human health. International Journal of Livestock Production, 2(4), 45-54. [URL].

Bourne, M. C. (1978). Texture profile analysis. Food Technology, 32, 62-66. [URL].

Choi, Y. S., Jeong, J. Y., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., & et al. (2008). Effects of dietary fiber from rice bran on the quality characteristics of emulsion-type sausages. Food Science of Animal Resources, 28(1), 14-20. (Korean) [DOI].

Choi, Y. S., Kim, H. W., Hwang, K. E., Song, D. H., Park, J. H., Lee, S. Y., & et al. (2012). Effects of pumpkin (Cucurbita maxima Duch.) fiber on physicochemical properties and sensory characteristics of chicken frankfurters. Food Science of Animal Resources, 32(2), 174-183. [DOI].

Correa, D., Castillo, P. M. M., & Martelo, R. J. (2018). Effect of the fat substitution on the rheological properties of fermented meat emulsions. Contemporary Engineering Sciences, 13(13), 619-627. [DOI].

Duncan, T. E., Duncan, S. C., & Li, F. (1998). A comparison of model-and multiple imputation-based approaches to longitudinal analyses with partial missingness. Structural Equation Modeling: A Multidisciplinary Journal, 5(1), 1-21. [DOI].

Eim, V. S., Simal, S., Rosselló, C., & Femenia, A. (2008). Effects of addition of carrot dietary fibre on the ripening process of a dry fermented sausage (sobrassada). Meat Science, 80(2), 173-182. [PMID: 22063320] [DOI].

El-Magoli, S. B., Laroia, S., & Hansen, P. (1996). Flavor and texture characteristics of low fat ground beef patties formulated with whey protein concentrate. Meat Science, 42(2), 179-193. [PMID: 22060683] [DOI].

Emaga, T. H., Andrianaivo, R. H., Wathelet, B., Tchango, J. T., & Paquot, M. (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chemistry, 103(2), 590-600. [DOI].

Erdem, N., & Alici, H. (2023). Effects of flour additives on gluten-free chicken croquettes. Fleischwirtschaft, 103, 76-85. [URL].

Femenia, A., LEFEBVRE, A. C., THEBAUDIN, J. Y., Robertson, J., & BOURGEOIS, C. M. (1997). Physical and sensory properties of model foods supplemented with cauliflower fiber. Journal of Food Science, 62(4), 635-639. [DOI].

Flores, M., Giner, E., Fiszman, S., Salvador, A., & Flores, J. (2007). Effect of a new emulsifier containing sodium stearoyl-2-lactylate and carrageenan on the functionality of meat emulsion systems. Meat Science, 76(1), 9-18. [PMID: 22064186] [DOI].

Gannoruwa, S. (2008). Development of banana flour based baby food products University of Sri Jayewardenepura, Nugegoda]. [URL]

Garcıa, M., Dominguez, R., Galvez, M., Casas, C., & Selgas, M. (2002). Utilization of cereal and fruit fibres in low fat dry fermented sausages. Meat Science, 60(3), 227-236. [PMID: 22063393] [DOI].

Goswami, M., Sharma, B. D., Mendiratta, S. K., & Pathak, V. (2021). Quality improvement of refined wheat flour cookies with incorporation of functional ingredients. Journal of Food Processing and Preservation, 45(4), e14945. [PMID: 24426017] [PMCID: PMC3791239] [PMCID: PMC3791239] [DOI].

Keeton, J. T. (1983). Effects of fat and NaCl/phosphate levels on the chemical and sensory properties of pork patties. Journal of Food Science, 48(3), 878-881. [DOI].

Kumar, R., Goswami, M., Pathak, V., Bharti, S. K., Verma, A. K., Rajkumar, V., & Patel, P. (2023). Utilization of poultry slaughter byproducts to develop cost effective dried pet food. Animal Nutrition and Feed Technology, 23(1), 165-174. [DOI].

Kumar, R., Goswami, M., Pathak, V., & Singh, A. (2024). Effect of binder inclusion on poultry slaughter house byproducts incorporated pet food characteristics and palatability. Animal Nutrition and Feed Technology, 24(1), 177-191. [DOI].

Kumar, R., Goswami, M., Pathak, V., & Verma, A. K. (2023). Quality improvement of poultry slaughter house byproducts based pet food with incorporation of fiber-rich vegetable powder. Exploratory Animal & Medical Research, 13(1). [DOI].

Kumar, V., Biswas, A. K., Sahoo, J., Chatli, M. K., & Sivakumar, S. (2013). Quality and storability of chicken nuggets formulated with green banana and soybean hulls flours. Journal of Food Science and Technology, 50(6), 1058-1068. [PMID: 24426017] [PMCID: PMC3791239] [DOI].

Kumar, Y., Shukla, P., Singh, P., Tanwar, V., Thori, M., & Sharma, V. (2015). Effect of dried carrot powder incorporation on quality attributes of chicken cutlets. Journal of Ready to Eat Food, 2(3), 89-95. [URL].

Lai, L. S., Liu, Y. L., & Lin, P. H. (2003). Rheological/textural properties of starch and crude hsian-tsao leaf gum mixed systems. Journal of the Science of Food and Agriculture, 83(10), 1051-1058. [DOI].

Lee, M., Han, D., Jeong, J., Choi, J., Choi, Y., Kim, H., & et al. (2008). Effect of kimchi powder level and drying methods on quality characteristics of breakfast sausage. Meat Science, 80(3), 708-714. [PMID: 22063587] [DOI].

Mitra, A., Tripathy, A. K., Singh, R. K., & Bujarbaruah, K. M. (2024). Transforming the Indian Livestock Sector In - Transformation of agri-food systems. In Transformation of Agri-Food Systems (pp. 173-191). Springer. DOI

Mohapatra, D., Mishra, S., & Sutar, N. (2010). Banana and its by-product utilisation: an overview. Journal of Scientific and Industrial Research, 69(5), 323-329. [URL].

Murphy, E. W., Criner, P. E., & Gray, B. C. (1975). Comparisons of methods for calculating retentions of nutrients in cooked foods. Journal of Agricultural and Food Chemistry, 23(6), 1153-1157. [PMID: 1238446] [DOI].

Reynolds, H. L. (1989). Association of official analytical chemists: 1964-1988. Reviews of Environmental Contamination and Toxicology: Continuation of Residue Reviews, 109-136. [DOI].

Rodríguez-Ambriz, S., Islas-Hernández, J., Agama-Acevedo, E., Tovar, J., & Bello-Pérez, L. (2008). Characterization of a fibre-rich powder prepared by liquefaction of unripe banana flour. Food Chemistry, 107(4), 1515-1521. [DOI].

Sánchez-González, I., Rodríguez-Casado, A., Careche, M., & Carmona, P. (2009). Raman analysis of surimi gelation by addition of wheat dietary fibre. Food Chemistry, 112(1), 162-168. [DOI].

Sano, T., Noguchi, S. F., Tsuchiya, T., & Matsumoto, J. J. (1988). Dynamic viscoelastic behavior of natural actomyosin and myosin during thermal gelation. Journal of Food Science, 53(3), 924-928. [DOI].

Sarawong, C., Schoenlechner, R., Sekiguchi, K., Berghofer, E., & Ng, P. K. (2014). Effect of extrusion cooking on the physicochemical properties, resistant starch, phenolic content and antioxidant capacities of green banana flour. Food Chemistry, 143, 33-39. [PMID: 24054209] [DOI].

Troutt, E., Hunt, M., Johnson, D., Claus, J., Kastner, C., & Kropf, D. (1992). Characteristics of low-fat ground beef containing texture-modifying ingredients. Journal of Food Science, 57(1), 19-24. [DOI].

Turhan, S., Sagir, I., & Ustun, N. S. (2005). Utilization of hazelnut pellicle in low-fat beef burgers. Meat Science, 71(2), 312-316. [PMID: 22064231] [DOI].

W. H. O. (2003). Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation. World Health Organization.

Wang, J., Huang, H. H., & Chen, P. S. (2017). Structural and physicochemical properties of banana resistant starch from four cultivars. International Journal of Food Properties, 20(6), 1338-1347. [DOI].

Zlatkis, A., Zak, B., & Boyle, A. J. (1953). A new method for the direct determination of serum cholesterol. The Journal of Laboratory and Clinical Medicine, 41(3), 486-492. [PMID: 13035283] [URL].