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Development of Ready-To-Eat 'Banana Flower Keropok Lekor' by using Retort Processing Technology (Banana Blossom)

Noormaisarah Soulihen[1], Faridah Kormin[1]*

1 *Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600, Pagoh, Muar, Johor, MALAYSIA.*

*Corresponding Author: faridahk@uthm.edu.my
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Abstract

The development and evaluation of a novel plant-based alternative to traditional Malaysian keropok lekor presents an innovative approach to meet evolving consumer preferences in the ready-to-eat (RTE) food sector. This investigation focuses on the four formulations of keropok lekor incorporating banana flower in combination with shredded coconut, oyster mushroom, and potato as key ingredients. Physicochemical assessments focus on critical quality indicators such as moisture content, colour metrics, pH levels, and texture profile analysis (TPA). Formulation 3 exhibited moisture levels (56.02%) which is the most comparable to traditional products while other formulation in the range of 50%-60%. From the result, the pH is range from 6.00 until 6.94 and hardness measurements exhibited a broad range from 1612.71 to 5295.18. Sensory parameters under examination include appearance, aroma, colour, texture, and taste characteristics for 50 untrained panellists. The nutritional value indicated this product as a suitable alternative for calorie-conscious consumers due to the total fat content was determined to be 2.8g/100g, the energy content analysis revealed 189 kcal/100g and the sodium content is 412.8mg/100g. This research responds to the growing demand for convenient RTE food options, particularly among urban consumers with time constraints, while potentially offering a sustainable and innovative approach to traditional snack food production.

1. Introduction

Keropok lekor, a fish-based food product, maintains significant commercial prominence in Malaysian cuisine. The product requires daily production cycles to meet consumer demand across multiple distribution channels, including street vendors, night markets, and educational institution food services. Geographical distribution analysis indicates higher market penetration in Terengganu and adjacent East Coast states, while the product is commercially available throughout Malaysia [1]. Mackerel species have been identified as the optimal fish variety for keropok lekor production, based on their textural and organoleptic properties. Despite significant market demand, keropok lekor's commercial scalability remains constrained due to inherent product stability limitations, specifically its abbreviated shelf life at ambient temperature conditions.

The development of Ready-to-Eat (RTE) Banana Flower Keropok Lekor represents a strategic response to current market demands, incorporating innovative processing methods and functional ingredients to address existing product limitations. This novel formulation utilizes banana blossom as a key functional component, processed through retort technology to ensure product stability and shelf-life enhancement. The initiative corresponds to empirical market research indicating a significant shift in consumer preferences toward convenient, nutritionally optimized food products, driven by contemporary lifestyle changes and evolving consumption patterns. Food industry manufacturers have adapted their production strategies to align with these market dynamics, focusing on developing RTE products that simultaneously satisfy convenience requirements and nutritional standards. The research objectives encompass three primary aims: the implementation of retort processing technology in RTE Banana Flower Keropok Lekor production, comprehensive analysis of physicochemical properties and nutritional parameters through sensory evaluation, and a comparative assessment of nutritional compositions between fried and non-fried variants of the product. This methodological approach ensures systematic evaluation of product viability while maintaining stringent quality control parameters for both domestic and commercial consumption contexts.

2. Materials and Methods

2.1 Materials

Banana heart, wheat flour, tapioca starch, baking powder, salt, grated coconut, oyster mushroom and potato was purchased at the supermarket in Pagoh Jaya, Pagoh.

2.2 Physicochemical Properties Analysis

2.2.1 Moisture content

Moisture content analysis was conducted and each formulation of ready-to-eat (RTE) 'Banana Flower Keropok Lekor', 5.0 g samples were weighed and placed in aluminium dishes. The samples were subjected to thermal processing at 170°C for 20 minutes.

2.2.2 Colour

Colour analysis was performed using a handheld spectrophotometer following the CIE L*a*b* colour space system. The colour parameters measured included lightness (L*), redness (a*), and yellowness (b*) values for both fried and non-fried formulations of ready-to-eat (RTE) 'Banana Flower Keropok Lekor'. All measurements were conducted as described by [2]to ensure data reliability.

2.2.3 pH

The pH measurement was conducted using a calibrated pH meter. Each formulation of keropok lekor banana flower (20 g) was homogenized with 20 mL of deionized distilled water for 2 minutes following the method described by [3].

2.2.4 Texture Profile Analysis (TPA)

Texture Profile Analysis (TPA) was performed to determine the firmness of each formulated keropok lekor banana flower. The samples were cut parallel to the principal axis of the muscle fiber into uniform dimensions of 1 cm × 2 cm × 5 cm for standardized measurements. They were then sheared perpendicular to the fiber axis until 80% penetration was achieved, and the biting force was measured in Newtons. This analysis was replicated three times to ensure accuracy. The firmness parameter of each formulated sample was assessed, providing valuable insights into the textural attributes of the keropok lekor banana flower.

2.3 Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale as described, with ratings ranging from 1 (dislike extremely) to 9 (like extremely) (Addo-Preko *et al.,* 2023). A panel of 60 untrained panellist evaluated both fried and non-fried formulations of keropok lekor banana flower [3]. The sensory attributes assessed included appearance, aroma, colour, texture, taste, and overall acceptance. Each formulation was evaluated for panellists' acceptability based on these sensory parameters.

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2.4 Nutritional Value

2.4.1 Carbohydrate Value

The total carbohydrate content of keropok lekor banana flower was determined using the differential method, where the percentage of other proximate components was subtracted from 100%. This calculation followed the equation.

$$\text{Total carbohydrate (\%)} = 100\% - (\text{Protein\%} + \text{Moisture\%} + \text{Ash\%} + \text{Total Fat\%}) \quad (1)$$

2.4.2 Fat Value

Crude fat content was determined using the Soxhlet extraction method according to AOAC (2000) protocols. The fat content was calculated using the equation, where W1 represents the sample weight in grams, W2 denotes the extraction beaker weight in grams, and W3 indicates the combined weight of the extraction beaker and fat in grams.

$$\text{Fat (\%)} = (W3-W1)/W2 \times 100 \quad (2)$$

2.4.3 Protein Value

The protein content of keropok lekor banana flower was determined using the Kjeldahl method in accordance with AOAC (2000) specifications. The analysis involved treating 1 g of sample with catalysts prior to the digestion process. The nitrogen content was quantified by measuring the amount of HCl in both the sample and digested blank, using the equation, where A and B represent the sample and blank titration values, respectively.

$$\%N = [0.1 \times (A-B) \times 14.007 \times 100] / [1000 \times \text{weight of sample (g)}] \quad (3)$$

2.4.4 Energy Value

The energy content of keropok lekor banana flower was determined following the Association of Official Analytical Chemists method (AOAC, 2000). The calculation involved multiplying the measured quantities of macronutrients by their respective physiological energy values: 4 kcal/g for both carbohydrates and proteins, and 9 kcal/g for fats. The total energy content was then derived using the equation.

$$\text{Energy (kcal)} = (4 \times \text{carbohydrates g}) + (4 \times \text{protein g}) + (9 \times \text{fat g}) \quad (4)$$

2.4.5 Total Sugar Value

Total sugar content was determined using the Lane-Eynon titration method according to AOAC Official Method 923.09 (2000). Prior to sample analysis, the sucrose solution underwent standardization.

2.4.6 Sodium Value

Sodium content was quantified using the Mohr titration method. The sodium ion concentration in keropok lekor banana flower was determined by titrating chloride ions with silver nitrate ($AgNO_3$). The percentage of sodium chloride content was calculated using the equation.

$$\text{NaCl (\%)} = (V \times N \times F \times 0.0585 \times 100)/m \quad (5)$$

2.4.7 Ash Value

Total ash content analysis was performed utilizing the standardized AOAC (2019) method. Quantitative ash content determination was executed utilizing the following mathematical expression [4].

$$\text{Ash content (\%)} = [(\text{Weight of ash}) / (\text{Weight of sample})] \times 10 \quad (6)$$

2.5 Statistical Analysis

For this research, the Statistical Package for the Social Sciences (SPSS) version 27 by using compare means in ONE WAY ANOVA were used for the statistical analysis. The analysis for each physicochemical properties was carried out in triplicate. All results were expressed as mean ± standard deviation (SD) to show variation within different parameters. Differences were considered significant when $p<0.05$.

3. Result and Discussion

3.1 Physicochemical Properties Analysis

3.1.1 Moisture Content

Moisture content is a critical parameter that influences multiple aspects of food products, including shelf-life, freshness, quality, bacterial resistance, physical appearance, texture, flavor, and weight. Analysis of moisture content in Ready-to-Eat (RTE) keropok lekor banana flower revealed statistically significant differences ($p<0.05$) among all formulations, indicating that the incorporation of banana flower substantially affected the product's moisture properties. The control formulation demonstrated a moisture content of 58.28±0.37%, which aligns with the conventional range (55-60%) previously documented for traditional fish-based keropok lekor [5]. Among the modified formulations, Formulation 3 exhibited moisture levels (56.02±0.75%) most comparable to traditional products, though with notable variability as indicated by its higher standard deviation. Formulation 1 showed intermediate moisture content (53.68±0.62%), while Formulations 2 and 4 displayed lower moisture levels of 50.77±0.25% and 51.96±0.25%, respectively, with improved consistency as evidenced by their reduced standard deviations. The decreased moisture content observed in Formulations 2 and 4 suggests potential benefits for product shelf stability, addressing a common challenge in plant-based protein product development.

Table 1 Moisture of different formulation in RTE keropok lekor banana flower

Formulation	Moisture (%)
Control	58.28±0.37^{d}
1	53.68±0.62^{c}
2	50.77±0.25^{b}
3	56.02±0.75^{a}
4	51.96±0.25^{a}

Note: Response are means of triplicate determination ± Standard Deviation (SD)

3.1.2 Colour

Colourimetric analysis of keropok lekor banana flower formulations revealed significant differences ($p<0.05$) in lightness (L*), redness (a*), and yellowness (b*) parameters. The control formulation established a baseline L* value of 50.14 ± 0.27, demonstrating the relationship between moisture content and colour development through Maillard reactions and caramelization during thermal processing, which subsequently influenced product stability and texture characteristics. An inverse correlation was observed between banana flower incorporation and product lightness, with L* values progressively decreasing from the control (50.14 ± 0.27) to Formulation 4 (56.93 ± 0.76). The a* values ranged from 2.73 ± 0.17 to 1.99 ± 0.72, with banana flower formulations exhibiting reduced redness compared to the control. Analysis of b* values demonstrated variations in yellowness, with the control measuring 11.36 ± 0.20, while experimental formulations showed variable yellow chromaticity.

These results correspond with previous findings by [6], who reported similar colour modifications in plant-based substitutions while maintaining consumer acceptability. The observed L* values (45-65) fell within the established acceptable range for modified keropok lekor formulations. The chromatic variations can be attributed to three primary factors, the inherent pigmentation of banana flower constituents, modified protein-carbohydrate ratios affecting Maillard reaction kinetics, and interactions between processing parameters and novel ingredient matrices.

Table 2 Colour of different formulation in RTE keropok lekor banana flower

Formulation	L*	a*	b*
Control	50.14 ± 0.27^{b}	5.56± 0.50^{b}	11.36± 0.20^{ab}
1	32.00 ± 0.15^{a}	2.73 ± 0.17^{a}	15.70 ± 0.21^{c}
2	50.87 ± 0.65^{ab}	2.33 ± 0.50^{a}	8.23 ± 0.25^{a}
3	48.80 ± 0.41^{a}	5.27 ± 0.31^{b}	13.90± 0.13^{bc}
4	56.93 ± 0.76^{c}	1.90 ± 0.72^{a}	8.77± 0.70^{a}

Note: Response are means of triplicate determination ± Standard Deviation (SD)

3.1.3 Ph

Analysis of pH values in Ready-to-Eat (RTE) keropok lekor banana flower formulations revealed not statistically significant differences (p<0.05) among all variants. The observed pH variations were attributed to multiple factors, including the natural acidity of banana flower tissue, processing conditions, component interactions, and the buffering effects of various formulation constituents. The control formulation established a baseline pH of 6.94±0.07, characteristic of traditional fish-based products. Among the modified formulations, Formulations 1 and 3 exhibited significantly lower pH values (6.00±0.06 and 6.03±0.02, respectively), which can be attributed to the presence of inherent organic acids in banana flower tissue, as documented by [6]. Conversely, Formulations 2 and 4 maintained pH levels (6.83±0.03 and 6.84±0.04, respectively) comparable to the control, with minimal standard deviations indicating excellent process consistency. The achievement of near-traditional pH values in these formulations suggests successful ingredient optimization, potentially enhancing both product safety and organoleptic characteristics typical of conventional keropok lekor.

Table 3 pH of different formulation in RTE keropok lekor banana flower

Formulation	pH
Control	6.94±0.07[a]
1	6.00±0.06[a]
2	6.83±0.03[a]
3	6.03±0.02[b]
4	6.84±0.04[b]

Note: Response are means of triplicate determination ± Standard Deviation (SD)

3.1.4 Texture Analysis Profile (TPA)

Texture profile analysis revealed statistically significant differences (p<0.05) in hardness values across all formulations of ready-to-eat (RTE) keropok lekor incorporating banana flower. The hardness measurements exhibited a broad range from 1612.71 to 5295.18. The control formulation, consisting of traditional fish-based keropok lekor, demonstrated the highest hardness value at 5295.18±89.04 N. A notable reduction in hardness was observed across all banana flower-containing formulations, suggesting structural modifications induced by this novel ingredient incorporation. Among the modified formulations, Formulation 2 exhibited the lowest hardness (1612.71±30.24 N), while Formulation 3 maintained the highest hardness value (3174.61±40.71 N) among the modified variants. Formulations 1 and 4 displayed intermediate hardness values of 2749.78±71.50 N and 2856.54±58.21 N, respectively.

The mechanistic basis for these textural variations can be attributed to several factors. The incorporation of banana flower components appears to modify the characteristic protein-starch interactions typically present in traditional keropok lekor matrices, corroborating the findings of [5] in similar composite snack systems. Furthermore, the introduction of natural fibers from banana flower creates matrix discontinuities, a phenomenon previously documented by [7], resulting in altered structural integrity compared to traditional formulations. The observed relationship between moisture content and hardness properties aligns with established patterns in conventional keropok products, as reported by [1]. The consistently lower hardness values across all modified formulations, compared to the control, indicate the substantial impact of banana flower incorporation on the textural properties of keropok lekor. Notably, Formulation 3 appears to achieve an optimal balance between novel ingredient incorporation and traditional textural characteristics, as evidenced by its relatively higher hardness values among the modified variants.

Table 4 Texture of different formulation in RTE keropok lekor banana flower

Formulation	Texture (Hardness) N
Control	5295.18±89.04[c]
1	2749.78±71.50[b]
2	1612.71±30.24[a]
3	3174.61±40.71[c]
4	2856.54±58.21[b]

Note: Response are means of triplicate determination ± Standard Deviation (SD)

3.2 Sensory Evaluation

Statistical analysis of the sensory evaluation data for ready-to-eat (RTE) keropok lekor banana flower revealed significant differences ($p<0.05$) across all formulations. The aroma evaluation demonstrated notable variations, with Formulations 3 and 4 exhibiting superior aromatic profiles, achieving mean scores of 8.62±0.63 and 6.54±1.18, respectively. These enhanced scores compared to Formulations 1 and 2 suggest that the selected banana flower incorporation levels positively influenced the product's olfactory characteristics, potentially due to the volatile compounds inherent in banana flowers, as previously documented by [8]. The colour evaluation metrics displayed considerable variation, ranging from 4.19±0.86 to 8.69±0.54, with Formulation 3 achieving the highest mean score. This trend was similarly reflected in appearance ratings, where Formulation 3 garnered the highest mean score of 8.56±0.60, indicating optimal ingredient proportioning and enhanced aesthetic attributes in the final product.

Formulation 3, representing the non-fried variant of keropok lekor banana flower, demonstrated superior acceptance ratings across multiple sensory parameters. This formulation, comprising specific ingredients including grated coconut, oyster mushroom, and potato, exhibited particularly appealing visual characteristics. The balanced chromatic distribution of its constituent ingredients created a complementary colour profile, where the light, neutral tones of grated coconut and potato effectively contrasted with the distinct earthy pigmentation of oyster mushrooms. This thoughtful colour variation contributed to enhanced visual complexity and perceived freshness; factors typically associated with positive panellist acceptance.

Textural analysis revealed significant variations across formulations, with Formulation 3 exhibiting superior texture characteristics (8.65±0.68). This enhanced textural profile can be attributed to the optimized incorporation ratio of banana flower, where its inherent fiber content and moisture-binding properties likely contributed to favourable structural modifications in the product matrix. In taste assessment, Formulation 3 demonstrated the highest score (8.67±0.64), suggesting optimal flavour development through synergistic interactions between banana flower components and traditional keropok lekor constituents. The overall acceptability metrics aligned consistently with individual sensory parameters, with Formulation 3 achieving the highest acceptance score (8.75±0.52). This superior overall acceptance indicates successful integration of the novel ingredient while maintaining desirable organoleptic qualities, achieved through strategic incorporation of banana flower into the formulation matrix.

Table 5 Sensory evaluation of different formulation in RTE keropok lekor banana flower

Formulation	Aroma	Colour	Appearance	Texture	Taste	Overall Acceptance
1	4.06±0.90^{a}	4.19±0.86^{a}	4.17±0.89^{a}	4.60±0.66^{a}	3.85±0.99^{a}	3.92±0.97^{a}
2	4.00±1.10^{a}	4.08±1.01^{a}	4.10±1.00^{a}	4.63±0.87^{a}	3.71±1.22^{a}	3.96±1.13^{a}
3	8.62±0.63^{c}	8.69±0.54^{c}	8.56±0.60^{c}	8.65±0.68^{c}	8.67±0.64^{c}	8.75±0.52^{c}
4	6.54±1.18^{b}	6.40±1.11^{b}	6.58±1.03^{b}	6.62±0.93^{b}	6.79±1.11^{b}	6.81±1.03^{b}

Note: Result was expressed mean ± Standard Deviation (SD), followed by the same letter in the same row within factors that were significantly different from one another ($p>0.05$) according to Turkey's post hoc test.

3.3 Nutritional Value

The developed ready-to-eat (RTE) keropok lekor banana flower formulation exhibited a moisture content of 45.0g/100g, which is comparatively lower than commercial keropok lekor variants. This reduced moisture content is characteristic of RTE food products, strategically designed to enhance shelf-life stability. The energy content analysis revealed 189 kcal/100g, representing a moderate caloric value significantly lower than conventional commercial keropok lekor products, which typically range from 450-500 kcal/100g, positioning this product as a suitable alternative for calorie-conscious consumers. The carbohydrate content was determined to be 45g/100g, primarily derived from tapioca flour and the complex carbohydrates inherent in banana blossom. This aligns with the 2017 Malaysian Recommended Nutrient Intakes (RNI) guidelines, which recommend that 45-65% of daily energy intake should be derived from carbohydrates. The protein content analysis indicated 5.1g/100g, representing a moderate protein level for a plant-based product. This formulation can supply roughly 10% of the daily required protein intake (50g), making it ideal as a supplemental protein source for vegan and vegetarian dietary patterns even if it is not meant to be a primary protein source.

The total fat content was determined to be 2.8g/100g, notably lower than conventional fish-based keropok lekor, positioning this product as a reduced-fat alternative. This value falls well within the 1999 Malaysian Dietary Guidelines, which recommend a minimum dietary fat intake of 15% kcal (equivalent to 33g based on a 2000 kcal diet). The moisture content of 45.0g/100g is consistent with expectations for non-fried keropok lekor formulations, maintaining textural characteristics comparable to commercial fish-based variants. Mineral content analysis revealed 1.4g/100g, representing a favourable mineral profile for a plant-based product. This finding is particularly significant given the current emphasis on calcium, iodine, iron, phosphorus, selenium, and zinc content in plant-based alternatives to animal products. Banana flower's inherent mineral composition, including iron, copper, and magnesium, contributes to its efficacy as a meat substitute. The sodium content was determined to be 412.8mg/100g, indicating moderate sodium levels within the formulation. This value aligns with dietary recommendations, considering the Malaysian Recommended Nutrient Intake (RNI) 2017 guidelines, which establish a daily sodium requirement of 1500mg for adults aged 19 years and above.

Table 6 Nutritional value of different formulation in RTE keropok lekor banana flower

Parameter	Unit	Value
Energy content	kcal/100 g	189
Total carbohydrate	g/100g	35.8
Protein content	g/100g	5.1
Total fat content	g/100g	2.8
Moisture	g/100g	45.0
Ash	g/100g	1.4
Total sugar	g/100g	1.4
Sodium	mg/100g	412.8

4. Conclusion

Analysis of ready-to-eat (RTE) keropok lekor formulations incorporating banana flower revealed distinct physicochemical, sensory, and nutritional characteristics. Moisture content varied significantly across formulations, with Formulation 3 exhibiting the highest value (56.02 ± 0.75%). Colour analysis demonstrated Formulation 3 displaying peak redness (a^* = 5.27 ± 0.31) while pH values ranged from 6.00 to 6.84. Sensory evaluation indicated favourable acceptability with hedonic scores of 7-9, with Formulation 3 excelling in taste and overall acceptance. Nutritional analysis of the optimized formulation revealed an energy content of 189 kcal/100g, with notable protein content (35.8 g/100g), moderate carbohydrate (5.1 g/100g) and low lipid (2.8 g/100g) levels, alongside optimal moisture content (45.0 g/100g), ash and total sugar contents (1.4 g/100g), and sodium levels (412.8 mg/100g), demonstrating its potential as a nutritionally enhanced alternative to traditional variants.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Noormaisarah Soulihen, Faridah Kormin; **data collection:** Noormaisarah Soulihen; **analysis and interpretation of results:** Noormaisarah Soulihen, Faridah Kormin; **draft manuscript preparation:** Noormaisarah Soulihen, Faridah Kormin. All authors reviewed the results and approved the final version of the manuscript.*

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