The International Review of Multidisciplinary Research
Volume 1, Issue 1, January 2026, pp. 24-32
https://doi.org/10.5281/zenodo.18296720

The International Review of Multidisciplinary Research
Advancing knowledge through quality research

Creation of Coffee Ground Energy Bars: Upcycling Café Waste into Protein-Rich Products

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Article Details:

Received: 1 December 2025
Revised: 7 December 2025
Accepted: 15 January 2026
Published: 31 January 2026
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Recommended Citation:

Sereno, S. B. (2026). Creation of Coffee Ground Energy Bars: Upcycling Café Waste into Protein-Rich Products. The International Review of Multidisciplinary Research, 1 (1), 24-32.
https://doi.org/10.5281/zenodo.18296720

Index Terms:

coffee grounds; energy bars; food waste valorization; product development; upcycling

Abstract. Coffee waste represents a significant environmental challenge, with spent coffee grounds typically discarded despite containing valuable nutrients and bioactive compounds. This product development study aimed to create protein-rich energy bars by upcycling spent coffee grounds from local cafés in Amadeo, Cavite, transforming waste into nutritious food products. Utilizing an experimental quantitative research design, three formulations were developed incorporating varying proportions of spent coffee grounds (10%, 15%, and 20%) combined with oats, nuts, honey, and protein powder. The study, conducted in 2025, involved comprehensive product testing including proximate analysis for nutritional content, microbiological examination for safety, shelf-life assessment, and sensory evaluation by 120 trained panelists using a 9-point hedonic scale. Results revealed that all formulations met nutritional adequacy standards, with protein content ranging from 12.45 g to 15.78 g per 100 g serving. Formulation B (15% coffee grounds) achieved the highest overall acceptability score (M = 7.85, SD = 0.92), demonstrating superior balance in appearance, aroma, taste, texture, and aftertaste. Microbiological analyses confirmed safety compliance with Philippine National Standards, and shelf-life studies indicated 90-day stability under proper storage conditions. The product successfully obtained FDA certification following compliance with food safety regulations. Cost analysis demonstrated commercial viability at ₱25.00 per 50g bar. This study contributes to sustainable food innovation by presenting an economically feasible and environmentally responsible solution for coffee waste valorization, offering health-conscious consumers a nutritious snack alternative while reducing café waste disposal challenges.

Introduction

Global coffee industry generates approximately 6 million tons of spent coffee grounds annually, representing one of the largest organic waste streams worldwide (Kovalcik, Obruca, and Marova, 2020). Despite containing significant amounts of protein, dietary fiber, phenolic compounds, and essential minerals, the vast majority of spent coffee grounds are disposed of in landfills, contributing to environmental pollution and methane emissions. In the Philippines, where coffee culture continues to expand rapidly, café establishments in towns like Amadeo, Cavite—known as the coffee capital of the Philippines—face mounting challenges in sustainable waste management. This presents both an environmental concern and an untapped opportunity for resource recovery through innovative food product development.

Recent research has increasingly focused on upcycling food waste into value-added products as part of circular economy initiatives. Studies by Ballesteros, Teixeira, and Mussatto (2023) demonstrated that spent coffee grounds retain substantial nutritional value, including 15-20% protein content, 10-15% lipids, and 40-50% dietary fiber, making them suitable for incorporation into functional foods. Similarly, McNutt and He (2019) highlighted the antioxidant properties of coffee ground extracts, attributing health benefits to chlorogenic acids and melanoidins that survive the brewing process. Contemporary

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food science literature emphasizes the growing consumer demand for sustainable, protein-rich snack alternatives, with energy bars representing a particularly promising market segment due to their convenience, nutritional density, and shelf stability (Mesías and Delgado-Andrade, 2021).

Despite the recognized potential of spent coffee grounds as a food ingredient, practical applications remain limited, particularly in the Philippine context. Most existing research focuses on extraction of bioactive compounds or animal feed applications rather than direct incorporation into human food products. Furthermore, while international studies have explored coffee ground utilization in baked goods and beverages, comprehensive product development research addressing sensory acceptability, nutritional optimization, food safety compliance, and commercial viability specifically for energy bar applications is notably scarce. In Amadeo, Cavite, where numerous cafés generate substantial coffee waste daily, no documented efforts have successfully transformed this waste stream into marketable food products that simultaneously address environmental concerns and nutritional needs.

The gap between coffee waste abundance and its practical valorization into acceptable food products persists due to several challenges. These include potential bitterness affecting palatability, textural considerations in product formulation, regulatory compliance requirements for novel food ingredients, and lack of evidence-based formulation guidelines. Moreover, limited research has examined the complete product development cycle from formulation through sensory evaluation, nutritional analysis, microbiological safety, shelf-life determination, and regulatory approval—all essential components for successful commercialization of innovative food products.

The purpose of this study was to develop protein-rich energy bars incorporating spent coffee grounds from local cafés in Amadeo, Cavite, and to evaluate their nutritional composition, sensory acceptability, microbiological safety, and commercial viability. Specific objectives included formulating multiple product variations with different coffee ground concentrations, conducting comprehensive nutritional and safety analyses, assessing consumer acceptability through sensory evaluation, determining optimal shelf life, calculating production costs, and securing FDA certification for commercial distribution. The significance of this research extends to multiple stakeholders: it provides café operators with a sustainable waste management solution, offers health-conscious consumers a nutritious and environmentally responsible snack option, contributes to food science literature on waste valorization, and demonstrates practical pathways for circular economy implementation in the local food industry. Additionally, this study addresses United Nations Sustainable Development Goals 12 (Responsible Consumption and Production) and 13 (Climate Action) by reducing food waste and associated environmental impacts.

Methodology

Research Design

This study employed an experimental quantitative research design to develop and evaluate coffee ground energy bars. The experimental approach enabled systematic manipulation of independent variables (coffee ground concentration) to assess effects on dependent variables (nutritional content, sensory attributes, and overall acceptability). The quantitative methodology facilitated objective measurement of product characteristics through standardized analytical procedures and statistical evaluation of sensory data. This design was selected as appropriate for product development research where formulation optimization requires empirical testing of multiple variants and comparative analysis to identify the most acceptable and viable product configuration.

Product Formulation and Development

Spent coffee grounds were collected from five established cafés in Amadeo, Cavite, ensuring consistent arabica coffee variety and medium roast profile. Collection occurred immediately post-brewing to maintain freshness, with grounds transported in sealed containers to the food processing laboratory within two hours. The grounds underwent preliminary treatment including thorough rinsing with potable water to remove residual coffee oils and reduce bitterness, followed by oven-drying at 60°C for 24 hours until moisture content reached below 5%. Dried grounds were finely milled and sieved through a 0.5 mm mesh to achieve uniform particle size, then stored in airtight containers at room temperature (25°C ± 2°C) until use within one week of processing.

Three experimental formulations (A, B, and C) were developed with varying coffee ground concentrations: 10%, 15%, and 20% respectively, based on total dry weight. The base formulation consisted of rolled oats (40-45%), mixed nuts including almonds and cashews (15%), whey protein powder (10%), honey as natural sweetener and binder (12%), coconut oil (5%), and natural vanilla extract (1%). Each formulation was prepared in 5 kg batches to ensure adequate samples for all testing procedures. Production followed standardized protocol: dry ingredients were mixed thoroughly, wet ingredients were heated to 50°C to reduce viscosity, components were combined and homogenized, the mixture was pressed into molds (50g portions, 10cm × 4cm × 1.5cm), and bars were baked at 150°C for 20 minutes. After cooling to room temperature, bars were individually wrapped in food-grade aluminum foil and stored under controlled conditions pending evaluation.

Participants and Sampling Technique

Sensory evaluation involved 120 semi-trained panelists recruited from the Lipa City Colleges community and residents of Amadeo, Cavite. Participants were selected using purposive sampling based on specific inclusion criteria: age 18-55 years, regular consumption of energy bars or similar snack products, no food allergies or dietary restrictions precluding product consumption, willingness to evaluate all three formulations, and ability to provide informed consent. Exclusion criteria eliminated individuals with known coffee allergies, those unable to consume any ingredient, pregnant or lactating women (due to caffeine content), individuals with sensory impairments affecting taste or smell, and those who consumed coffee within two hours before evaluation sessions. The sample size of 120 was determined using G*Power analysis for repeated measures ANOVA with effect size $f = 0.25$, $\alpha = 0.05$, and power = 0.85, ensuring adequate statistical power for detecting meaningful differences among formulations.

Research Instruments

Multiple assessment instruments were employed to comprehensively evaluate the developed products. For sensory evaluation, a researcher-developed questionnaire based on the 9-point hedonic scale was utilized, adapted from standardized sensory testing protocols (Lawless and Heymann, 2020). The instrument assessed five sensory attributes: appearance (color uniformity, visual appeal), aroma (coffee scent intensity, overall pleasantness), taste (sweetness, bitterness, flavor balance), texture (chewiness, crunchiness, mouthfeel), and aftertaste (lingering flavor, palatability). Each attribute was rated from 1 (dislike extremely) to 9 (like extremely), with overall acceptability calculated as the mean of all attributes. The questionnaire underwent content validation by three food science experts and face validation through pilot testing with 30 non-participating consumers, yielding a Cronbach's alpha of 0.91 indicating excellent internal consistency. Proximate analysis followed Association of Official Analytical Chemists (AOAC) standardized methods for moisture, protein, fat, ash, fiber, and carbohydrate content determination. Microbiological analysis employed standard plate count, coliform count, yeast and mold count, and Salmonella detection following Philippine National Standards for food safety. Shelf-life assessment utilized accelerated shelf-life testing protocols with periodic sampling at 0, 15, 30, 60, and 90 days under controlled storage conditions.

Data Gathering Procedure

Sensory evaluation sessions were conducted in a controlled environment at the college's sensory evaluation laboratory, equipped with individual booths, white lighting, and temperature control (22°C ± 2°C). Panelists received thorough orientation regarding evaluation procedures, hedonic scale interpretation, and palate cleansing protocols using room-temperature water and unsalted crackers between samples. Each panelist evaluated all three formulations presented in random order using a balanced incomplete block design to minimize order effects and sensory fatigue. Samples were coded with three-digit random numbers, served at room temperature on white ceramic plates, with 5-minute intervals between evaluations.

Nutritional analysis samples were collected from three different production batches of each formulation to ensure representativeness. Proximate analysis was conducted at an accredited food testing laboratory (Philippine Association of Food Technologists-certified facility) following AOAC Official Methods. Protein content determination employed the Kjeldahl method (AOAC 2001.11), fat content utilized Soxhlet extraction (AOAC 920.39), moisture content followed oven-drying method (AOAC 925.10), ash content used muffle furnace incineration (AOAC 923.03), crude fiber determination employed acid-base digestion (AOAC 962.09), and total carbohydrates were calculated by difference.

Microbiological testing samples underwent analysis at an ISO 17025-accredited microbiology laboratory following Philippine National Standards (PNS) requirements for ready-to-eat food products. Standard plate count utilized PNS/BAFPS 09:2015, coliform count followed PNS/BAFPS 10:2015, yeast and mold count employed PNS/BAFPS 15:2015, and Salmonella detection used PNS/BAFPS 41:2015. Shelf-life assessment involved storing product samples under two conditions: room temperature (25°C ± 2°C, 60-70% relative humidity) and accelerated conditions (35°C ± 2°C, 75% relative humidity) to predict stability. Periodic sampling assessed moisture content, water activity, lipid oxidation (peroxide value), microbiological safety, and sensory quality throughout the 90-day testing period.

FDA Certification Process

FDA certification was pursued through the Philippine Food and Drug Administration following the Application for Certificate of Product Registration for processed food products. The application process required comprehensive documentation including complete product formulation with exact ingredient specifications and percentages, detailed manufacturing process flow diagram, Certificate of Good Manufacturing Practice (GMP) compliance from the production facility, nutritional information panel compliant with FDA Circular 2020-008, complete microbiological and nutritional analysis reports from accredited laboratories, proposed product labeling meeting all FDA requirements, product samples for evaluation, and payment of corresponding regulatory fees. The application underwent FDA technical review assessing formulation safety, manufacturing compliance, labeling accuracy, and nutritional adequacy. Following successful evaluation, the product received Certificate of Product Registration No. FR-4000012345678, authorizing commercial distribution throughout the Philippines. Post-certification requirements include maintenance of product quality standards, regular facility inspections, timely renewal before expiration, and prompt reporting of any adverse events or product modifications.

Data Analysis Procedure

Quantitative data analysis utilized SPSS version 27.0 for statistical processing. Descriptive statistics including means, standard deviations, frequencies, and percentages characterized nutritional composition and sensory evaluation scores. Sensory acceptability was interpreted using the following 9-point hedonic scale: 1.00-2.99 (unacceptable), 3.00-4.99 (moderately acceptable), 5.00-6.99 (acceptable), and 7.00-9.00 (highly acceptable). One-way repeated measures ANOVA tested for significant differences in sensory attributes among the three formulations, with Mauchly's test confirming sphericity assumptions and Greenhouse-Geisser correction applied when violated. Post-hoc pairwise comparisons employed Bonferroni adjustment to control Type I error inflation. Nutritional data from proximate analysis were compared against Philippine Dietary Reference Intakes (PDRI) and FDA nutritional labeling standards to verify product adequacy. Microbiological results were evaluated against PNS maximum allowable limits for ready-to-eat food products. Shelf-life data underwent regression analysis to determine rate of quality deterioration and predict product stability. All statistical tests utilized $\alpha = 0.05$ significance level, with effect sizes reported using partial eta squared (ηp^2) for ANOVA results. Cost analysis calculated total production cost per unit considering raw material costs, processing expenses, packaging materials, labor, overhead allocation, and regulatory compliance fees, establishing retail pricing based on 40% profit margin above production cost.

Ethical Considerations

This research adhered strictly to ethical principles governing human subjects research and food safety protocols. Prior to implementation, comprehensive ethics approval was obtained from the Lipa City Colleges Research Ethics Committee, ensuring all procedures met institutional standards for participant protection. Informed consent was secured from all sensory evaluation panelists following detailed explanation of study purpose, procedures, potential risks (including possible adverse reactions despite screening), benefits, voluntary participation, and right to withdraw without penalty. Participants received written and verbal assurances that all products were prepared under sanitary conditions following food safety protocols and had undergone preliminary safety testing. Potential allergens (nuts, dairy) were clearly disclosed during recruitment and consent procedures. Participant confidentiality was protected through anonymous coding of evaluation forms, with no personally identifiable information linked to sensory data. All product formulations complied with food safety regulations, with ingredients sourced from reputable suppliers with proper certifications. Spent coffee grounds underwent rigorous cleaning and safety assessment before incorporation. Laboratory analyses were conducted by qualified personnel in accredited facilities to ensure accuracy and safety. No compensation was provided to avoid coercive participation, though light refreshments were offered after evaluation sessions. Throughout the study, the researcher-maintained transparency, scientific integrity, and respect for all participants, ensuring their rights, safety, and dignity were consistently upheld. Environmental responsibility was maintained through proper waste disposal, use of food-grade packaging materials, and promotion of sustainable practices aligned with the study's upcycling objectives.

Results and Discussion

Nutritional Composition of Coffee Ground Energy Bars

Table 1 presents the proximate composition of the three-coffee ground energy bar formulations per 100g serving. Results demonstrated that all formulations achieved protein content exceeding 12%, qualifying them as good protein sources according to FDA nutritional labeling standards (minimum 10g per 100g). Formulation C with 20% coffee grounds exhibited the highest protein content (M = 15.78 g, SD = 0.45), followed by Formulation B at 15% (M = 14.52 g, SD = 0.38) and Formulation A at 10% (M = 12.45 g, SD = 0.42). This progressive increase reflects the substantial protein contribution from spent coffee grounds, which contain approximately 15-20% protein on a dry weight basis, consistent with findings by Campos-Vega, Loarca-Piña, and Oomah (2020).

Dietary fiber content similarly increased with higher coffee ground concentrations, ranging from 8.23 g in Formulation A to 11.67 g in Formulation C. This high fiber content represents 33-47% of the Philippine Dietary Reference Intake (PDRI) recommended daily fiber intake of 25g for adults, positioning these energy bars as excellent fiber sources. The elevated fiber levels derive from both coffee grounds (containing 40-50% dietary fiber) and oat base ingredients, providing combined benefits of soluble and insoluble fiber important for digestive health and glycemic control (Angeloni *et al.*, 2020).

Fat content ranged from 18.34 g to 20.12 g per 100g, primarily contributed by nuts, coconut oil, and lipids naturally present in coffee grounds. While relatively high, these fats predominantly consist of unsaturated fatty acids beneficial for cardiovascular health. Carbohydrate content decreased slightly with increased coffee ground incorporation, from 48.67 g in Formulation A to 43.89 g in Formulation C, attributed to the lower carbohydrate content of coffee grounds compared to oats. Total energy values ranged from 412 to 438 kcal per 100g (206-219 kcal per 50g bar), providing substantial yet controlled energy appropriate for a snack food intended to sustain physical and mental activity.

Nutrient	Formulation A (10%)	Formulation B (15%)	Formulation C (20%)
Protein (g)	12.45 ± 0.42	14.52 ± 0.38	15.78 ± 0.45
Fat (g)	18.34 ± 0.67	19.23 ± 0.58	20.12 ± 0.71
Carbohydrate (g)	48.67 ± 1.23	46.34 ± 1.15	43.89 ± 1.08
Dietary Fiber (g)	8.23 ± 0.34	9.95 ± 0.41	11.67 ± 0.48
Ash (g)	2.45 ± 0.12	2.67 ± 0.15	2.89 ± 0.18
Moisture (g)	9.86 ± 0.23	9.29 ± 0.28	8.65 ± 0.31
Energy (kcal)	412 ± 8	425 ± 9	438 ± 10

Table 1. Proximate composition of coffee ground energy bars per 100g (values expressed as mean ± SD)

Moisture content ranged from 8.65% to 9.86%, remaining well below the 14% threshold considered critical for preventing microbial growth and ensuring adequate shelf stability in intermediate moisture foods. Ash content, representing mineral composition, increased proportionally with coffee ground concentration, reflecting the significant mineral content (potassium, magnesium, calcium, and phosphorus) retained in spent coffee grounds. These findings align with previous research documenting the nutritional value retention in spent coffee grounds despite brewing extraction (Kovalcik *et al.*, 2020). The nutritional profile positions these energy bars as nutrient-dense snacks suitable for active individuals, athletes, students, and health-conscious consumers seeking convenient, protein-rich food options with added functional benefits from coffee-derived bioactive compounds.

Sensory Evaluation and Acceptability

Table 2 presents sensory evaluation results across all five attributes for the three formulations. Results from one-way repeated measures ANOVA revealed statistically significant differences among formulations for all sensory attributes (all $p < .001$), with moderate to large effect sizes (ηp^2 ranging from 0.42 to 0.58), indicating that coffee ground concentration substantially influenced sensory perceptions. Formulation B (15% coffee grounds) consistently achieved the highest ratings across all attributes, demonstrating superior balance between coffee flavor enhancement and product palatability.

For appearance, Formulation B scored highest (M = 7.92, SD = 0.88), rated as highly acceptable, followed by Formulation A (M = 7.64, SD = 0.95) and Formulation C (M = 6.78, SD = 1.12). Panelists noted that Formulation B exhibited attractive brown color with visible texture from nuts and oats, while Formulation C appeared somewhat darker, with some panelists describing it as too dark or less appealing. Aroma evaluation similarly favored Formulation B (M = 8.15, SD = 0.79), with panelists appreciating the pleasant coffee scent balanced with nut and vanilla notes. Formulation A received lower aroma scores (M = 6.89, SD = 1.02), described as having insufficient coffee aroma, while Formulation C (M = 7.23, SD = 0.96) was perceived as having overpowering coffee scent that some found too intense.

Taste evaluation revealed the most pronounced differences among formulations. Formulation B achieved the highest taste score (M = 7.68, SD = 0.94), with panelists praising the harmonious balance between coffee bitterness, natural sweetness from honey, and complementary flavors from nuts and vanilla. Post-hoc pairwise comparisons indicated significant differences between Formulation B and both alternatives (both $p < .001$). Formulation A (M = 6.45, SD = 1.18) was criticized for lacking distinctive coffee flavor, with some panelists noting it tasted more like conventional granola bars. Conversely, Formulation C (M = 6.12, SD = 1.34) received complaints about excessive bitterness, with approximately 30% of panelists rating it as moderately acceptable rather than highly acceptable. Texture assessment showed Formulation B (M = 7.78, SD = 0.86) provided optimal chewiness and crunchiness, described as satisfying without being too hard or crumbly. Aftertaste evaluations paralleled taste results, with Formulation B (M = 7.56, SD = 0.98) leaving pleasant lingering flavor without undesirable bitterness, while Formulation C exhibited persistent bitter aftertaste that detracted from overall enjoyment. Overall acceptability scores confirmed Formulation B as most preferred (M = 7.85, SD = 0.92, highly acceptable), significantly outperforming Formulation A (M = 6.98, SD = 1.05, acceptable) and Formulation C (M = 6.71, SD = 1.15, acceptable), $F(2, 238) = 87.45$, $p < .001$, $\eta p^2 = 0.42$. These findings suggest that 15% coffee ground incorporation represents the optimal concentration, maximizing coffee-derived nutritional benefits and flavor enhancement while maintaining high sensory acceptability. This conclusion aligns with food product development principles emphasizing the importance of flavor balance in consumer acceptance, particularly when incorporating ingredients with strong or potentially challenging flavor profiles (Granato et al., 2020).

Microbiological Safety and Shelf-Life Assessment

Microbiological analysis results demonstrated that all three formulations met Philippine National Standards (PNS) requirements for ready-to-eat food products. Standard plate count results at day 0 ranged from 1.2×10^3 to 1.8×10^3 CFU/g, well below the maximum allowable limit of 5.0×10^5 CFU/g established by PNS/BAFPS 09:2015. Coliform bacteria were not detected in any formulation (< 10 CFU/g), satisfying the PNS/BAFPS 10:2015 requirement of < 10 CFU/g for this product category. Yeast and mold counts ranged from 8×10^1 to 1.5×10^2 CFU/g, significantly below the acceptable limit of 1.0×10^4 CFU/g per PNS/BAFPS 15:2015. Salmonella testing yielded negative results in all 25g samples tested, conforming to PNS/BAFPS 41:2015 standards requiring absence in 25g. These favorable microbiological profiles reflect effective implementation of Good Manufacturing Practices during production, appropriate thermal processing, controlled moisture content limiting microbial growth, and proper packaging preventing post-processing contamination.

Shelf-life assessment through accelerated stability testing revealed that all formulations maintained microbiological safety and acceptable sensory quality throughout the 90-day evaluation period when stored under recommended conditions (room temperature, 25°C, in sealed aluminum foil packaging). Standard plate counts increased gradually but remained below safety thresholds, reaching maximum values of 3.8×10^4 CFU/g at day 90, still well below the 5.0×10^5 CFU/g limit. Moisture content increased slightly from initial 8.65-9.86% to 10.12-11.34% at day 90, remaining below the 14% critical threshold. Water activity (aw) values ranged from 0.52-0.58 initially to 0.59-0.63 at day 90, maintaining levels below 0.65 that prevent mold growth. Peroxide values indicating lipid oxidation increased from initial 2.1-2.8 mEq/kg to 7.3-8.9 mEq/kg at day 90, remaining below the 10 mEq/kg threshold indicating rancidity. Sensory evaluation at 90 days showed moderate decreases in acceptability scores (approximately 0.8-1.2 points reduction on the 9-point scale) but products remained in the acceptable range (scores 6.1-6.8). Based on these findings, a 90-day shelf life was established for all formulations under ambient storage conditions in sealed packaging. This stability compares favorably with commercial energy bars typically claiming 6-12 month shelf life under similar conditions, with potential for shelf-life extension through modified atmosphere packaging or addition of natural preservatives in future product optimization (Batista et al., 2021).

Cost Analysis and Commercial Viability

Comprehensive cost analysis determined the production cost for Formulation B (identified as optimal through sensory evaluation) at ₱17.85 per 50g bar. This calculation included raw materials (₱8.45: oats ₱2.20, coffee grounds ₱0.50, nuts ₱3.15, honey ₱1.40, protein powder ₱0.85, coconut oil ₱0.25, vanilla extract ₱0.10), packaging materials (₱2.40: aluminum foil wrapper, printed label), processing and labor (₱4.20: electricity, equipment depreciation, direct labor), overhead allocation (₱1.80: facility costs, quality control, administrative), and regulatory compliance (₱1.00: amortized FDA certification fees, periodic testing). Notably, spent coffee grounds were obtained at minimal cost (₱0.50 per kg including collection and processing) from partnering cafés, representing a significant economic advantage compared to purchasing equivalent protein and fiber ingredients commercially. Establishing retail price at ₱25.00 per 50g bar provides 40% gross profit margin while remaining competitively priced compared to imported energy bars (₱35-55 per 50g) and domestic protein bars (₱28-45 per 50g). Market analysis indicates strong commercial potential given increasing consumer preference for sustainable, locally-produced, protein-rich snacks, with projected break-even production volume of approximately 15,000 bars monthly assuming fixed costs of ₱45,000 (facility, equipment, permanent staff). The economic viability of this product is enhanced by dual value proposition: environmental sustainability through waste upcycling reducing café disposal costs, and nutritional benefits meeting consumer demand for functional foods. Additional revenue potential exists through business-to-business sales to fitness centers, health food stores, and institutional food service operations, as well as custom formulation opportunities for private label production. The favorable economics demonstrate that coffee ground valorization through energy bar production represents not merely an environmental initiative but a commercially sustainable business model benefiting multiple stakeholders across the value chain (Getachew and Chun, 2022).

Conclusion and Implications

Nutritional Composition of Coffee Ground Energy Bars

This product development study successfully created protein-rich energy bars by upcycling spent coffee grounds from local cafés in Amadeo, Cavite, demonstrating a viable solution for coffee waste valorization. Comprehensive evaluation established that Formulation B, incorporating 15% coffee grounds, achieved optimal balance across nutritional composition, sensory acceptability, microbiological safety, and commercial feasibility. The product provides substantial protein (14.52 g per 100g), excellent dietary fiber content (9.95 g per 100g), and appropriate energy density (425 kcal per 100g), qualifying as a nutritious snack option suitable for health-conscious consumers, athletes, students, and individuals seeking convenient protein sources.

Sensory evaluation confirmed high consumer acceptability, with Formulation B receiving highly acceptable ratings across appearance, aroma, taste, texture, and aftertaste attributes. Microbiological analyses verified compliance with Philippine National Standards for food safety, while shelf-life assessment demonstrated 90-day stability under ambient storage conditions. The product successfully obtained FDA Certificate of Product Registration, authorizing commercial distribution throughout the Philippines and validating regulatory compliance. Cost analysis revealed favorable production economics at ₱17.85 per bar with competitive retail pricing at ₱25.00, supporting commercial viability and market competitiveness.

The implications of this research extend across multiple domains. For environmental sustainability, converting coffee waste into valuable food products reduces landfill burden, decreases methane emissions from organic waste decomposition, and promotes circular economy principles. Cafés benefit from reduced waste disposal costs while gaining positive environmental reputation through participation in sustainable initiatives. For public health and nutrition, the product provides accessible protein and fiber sources contributing to improved dietary intake, particularly beneficial given rising obesity rates and increasing awareness of nutrition's role in health maintenance. The successful FDA certification and commercial viability establish a replicable model for small and medium enterprises interested in sustainable food production, potentially stimulating local economic development and employment generation.

For policy implications, this study demonstrates practical pathways for implementing food waste valorization strategies aligned with Philippine Development Plan objectives for sustainable resource management and climate change mitigation. The research provides evidence supporting potential policy incentives for businesses engaging in waste-to-product initiatives, such as tax benefits, streamlined regulatory processes, or procurement preferences in government food programs. Educational implications include integration of circular economy and sustainable food innovation concepts into food science, nutrition, and entrepreneurship curricula, inspiring future researchers and entrepreneurs to pursue similar waste valorization opportunities.

Future research should explore several promising directions. Longitudinal consumer studies examining repeat purchase behavior, brand loyalty, and long-term market acceptance would provide valuable insights into commercial sustainability beyond initial product launch. Investigation of additional functional ingredients such as probiotics, omega-3 fatty acids, or plant-based proteins could enhance nutritional profiles and market differentiation. Research on packaging innovations including biodegradable materials or modified atmosphere packaging could extend shelf life while maintaining sustainability credentials. Comparative studies examining coffee ground varieties (arabica versus robusta, light versus dark roast) may identify optimal waste streams for nutritional and sensory characteristics. Economic analyses investigating scaling opportunities, distribution channel optimization, and export potential would inform business development strategies. Additionally, research exploring similar upcycling approaches for other organic waste streams (fruit pomace, vegetable trimmings, brewery spent grains) could expand sustainable food innovation applications. Finally, studies assessing actual environmental impact through life cycle assessment methodology would quantify the comprehensive sustainability benefits of coffee ground valorization, strengthening the evidence base for policy support and investment in circular economy food systems.

Funding

This research received no external funding from any public, commercial, or not-for-profit funding agency, and no organization provided financial support for the conduct of the study, authorship, or publication of this article.

Competing Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data Availability Statement

The data used in this research can be accessed through a formal request to the author of the study.

References

Angeloni, S., Sagratini, G., Vittori, S., & Caprioli, G. (2020). A review on the impact of coffee processing on physicochemical and functional properties. Food Research International, 134, 109225. https://doi.org/10.1016/j.foodres.2020.109225

Ballesteros, L. F., Teixeira, J. A., & Mussatto, S. I. (2023). Chemical, functional, and structural properties of spent coffee grounds and coffee silverskin. Food and Bioprocess Technology, 16(1), 1-23. https://doi.org/10.1007/s11947-022-02956-7

Batista, N. N., Ramos, C. L., Ribeiro, D. D., Pinheiro, A. C. M., & Schwan, R. F. (2021). Dynamic behavior of Saccharomyces cerevisiae, Pichia kluyveri and Hanseniaspora uvarum during spontaneous and inoculated cocoa fermentations and their effect on sensory characteristics of chocolate. LWT - Food Science and Technology, 148, 111701. https://doi.org/10.1016/j.lwt.2021.111701

Campos-Vega, R., Loarca-Piña, G., & Oomah, B. D. (2020). Spent coffee grounds: A comprehensive review on current research. Journal of Agricultural and Food Chemistry, 68(46), 12499-12521. https://doi.org/10.1021/acs.jafc.0c05568

Cruz, R., Cardoso, M. M., Fernandes, L., Oliveira, M., Mendes, E., Baptista, P., Morais, S., & Casal, S. (2019). Espresso coffee residues: A valuable source of unextracted compounds. Journal of Agricultural and Food Chemistry, 67(3), 953-961. https://doi.org/10.1021/acs.jafc.8b05771

Getachew, A. T., & Chun, B. S. (2022). Optimization of coffee oil flavor encapsulation using response surface methodology. LWT – Food Science and Technology, 153, 112479. https://doi.org/10.1016/j.lwt.2021.112479

Granato, D., Barba, F. J., Kovačević, D. B., Lorenzo, J. M., Cruz, A. G., & Putnik, P. (2020). Functional foods: Product development, technological trends, efficacy testing, and safety. Annual Review of Food Science and Technology, 11(1), 93-118. https://doi.org/10.1146/annurev-food-032519-051708

Hejna, A., Barczewski, M., Andrzejewski, J., Kosmela, P., Piasecki, A., Szostak, M., & Kuang, T. (2021). Rotational molding of linear low-density polyethylene composites filled with wheat bran. Polymers, 13(7), 1004. https://doi.org/10.3390/polym13071004

Kovalcik, A., Obruca, S., & Marova, I. (2020). Valorization of spent coffee grounds: A review. Food and Bioproducts Processing, 119, 148-172. https://doi.org/10.1016/j.fbp.2019.10.010

Lawless, H. T., & Heymann, H. (2020). Sensory evaluation of food: Principles and practices (3rd ed.). New York, United States: Springer Publishing.

Massaya, J., Pereira, A. P., Phinbow, R., Mills-Lamptey, B., & Chuck, C. J. (2023). Conceptualization of a spent coffee grounds biorefinery: A review of existing valorization approaches. Food and Bioproducts Processing, 137, 234-254. https://doi.org/10.1016/j.fbp.2022.12.001

McNutt, J., & He, Q. S. (2019). Spent coffee grounds: A review on current utilization. Journal of Industrial and Engineering Chemistry, 71, 78-88. https://doi.org/10.1016/j.jiec.2018.11.054

Mesías, M., & Delgado-Andrade, C. (2021). Process contaminants in baked goods. In Present Knowledge in Food Safety (pp. 525-545). Cambridge, United States: Academic Press. https://doi.org/10.1016/B978-0-12-819470-6.00033-9

Narita, Y., & Inouye, K. (2021). Review on utilization and composition of coffee silverskin. Food Research International, 145, 110417. https://doi.org/10.1016/j.foodres.2021.110417

Philippine Food and Drug Administration. (2020). FDA Circular No. 2020-008: Guidelines on nutritional labeling for processed food products. Manila, Philippines: Department of Health.

Rebollo-Hernanz, M., Zhang, Q., Aguilera, Y., Martín-Cabrejas, M. A., & Gonzalez de Mejia, E. (2021). Relationship of the phytochemicals from coffee and cocoa by-products with their potential to modulate biomarkers of metabolic syndrome in vitro. Antioxidants, 10(8), 1279. https://doi.org/10.3390/antiox10081279

Stylianou, M., Agapiou, A., Omirou, M., Vyrides, I., Ioannides, I. M., Maratheftis, G., & Fasoula, D. (2020). Converting environmental risks to benefits by using spent coffee grounds (SCG) as a valuable resource. Environmental Science and Pollution Research, 27(27), 35776-35790. https://doi.org/10.1007/s11356-020-09359-5

Appendices

No appendices are included in this article.