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Eggplant Nuggets: A Plant-based Solution for Sustainable Food System

Regine Manzanillo

Associate Professor, College of Business and Management, Isabela State University

Abstract

Plant-based meat substitutes address rising consumer demand and promote future food security. This study investigates reducing meat content in nuggets by incorporating eggplant, aiming to lessen the environmental and health impacts associated with livestock. The objective was to develop an acceptable meat-based product, specifically nuggets, with reduced meat content through eggplant substitution. It also aims to identify the significant differences on the sensory evaluation of panelists on the sensory characteristics of the developed product in terms of age and gender. An experimental approach was used, employing sensory evaluation with semantic and hedonic scale to assess the developed eggplant nuggets. Results indicate that eggplant nuggets exhibited acceptable sensory characteristics comparable to traditional meat nuggets. The study concludes that eggplant can be successfully incorporated into nugget formulations, offering a pathway to reduce meat consumption while maintaining consumer palatability. The study reveals that all treatments consisting of varying proportions of plant-based ingredients were both acceptable to consumers in terms of sensory level.

Keywords: Acceptability; Product Development; Eggplant; Meat substitutes

Introduction

The increasing global demand for convenient, ready-to-eat foods is driven by modern lifestyles, yet this trend often conflicts with rising health concerns related to the nutritional quality of such processed options (Oliveira et al., 2013). The food industry is actively responding by reformulating products to reduce unhealthy components while implementing transparent nutritional labeling, empowering consumers to make informed dietary choices.

The COVID-19 pandemic heightened consumer awareness of the importance of health and immunity, fueling a surge in interest in nutrient-rich diets (Alhusseini & Alqahtani, 2020). This presents a significant opportunity for the development of innovative and healthier food alternatives, particularly in the rapidly expanding market for meat substitutes (Zhang et al., 2022; Lee et al., 2020). While still a niche market in certain regions, the global meat substitute consumption is experiencing considerable growth, with a 23.7% increase in volume to 470 million kilograms in 2020 (Statistica, 2023). This expansion is largely driven by ethical considerations, environmental concerns, and the pursuit of health-conscious dietary patterns, most notably in North America and Europe (Szenderák et al., 2022).

In the Philippines, eggplant (Solanum melongena L.) presents a promising and underutilized resource for the development of sustainable meat substitutes. Accounting for over 30% of the country's vegetable production, eggplant offers significant economic and nutritional advantages (Cardello et al., 2022; Ahmad et al., 2022; Hautea et al., 2016). Eggplant is widely consumed in Asia due to its affordability,

availability, and favorable nutritional profile (Shelton, 2019). It provides essential minerals like magnesium, manganese, and copper, alongside vitamins and a high fiber content (14-20% dry weight) with low calories (P. Padmanabhan et al., 2016; Bidaramali et al., 2020). Furthermore, eggplant boasts a rich profile of antioxidants, including phenols, anthocyanins, and flavonoids, which have been linked to various health benefits (Gurbuz et al., 2018). Consumption of eggplant has been associated with reduced risks of heart disease, improved blood pressure and cholesterol levels, and potential benefits for managing diabetes due to its alpha-glucosidase and angiotensin compounds (Gurbuz et al., 2018). While not a primary source of protein compared to meat, eggplant's combination of vitamins, minerals, and dietary fiber positions it as a valuable and healthy carbohydrate option (Scorsatto et al., 2017; Sharma et al., 2022; Rashmi & Negi, 2020; Llauradó Maury, 2020; Vuong, 2017). Further investigation into how the amino acid profile of eggplant interacts with other ingredients in meat substitute formulations is warranted, as is exploring the impact of processing methods on the bioavailability of these key micronutrients.

Eggplant's high fiber content contributes to digestive health and satiety, making it a suitable alternative for individuals seeking weight management solutions (Higuera-Coelho, et.al 2025; Obu 2021; Kumar, et al 2020). The polyphenols and flavonoids present in eggplant exhibit significant anti-inflammatory and antioxidant properties, contributing to cardiovascular health. According to Lyngdoh et al. (2025), indigenous and exotic eggplant varieties contain bioactive compounds with strong antioxidant activity, highlighting their potential for nutraceutical applications. Similarly, Lyu et al. (2024) conducted a comprehensive evaluation of different Chinese eggplant varieties, confirming their high nutritional quality and potent antioxidant capacity. These findings underscore the role of eggplant as a valuable functional food for promoting cardiovascular well-being. While its protein content is relatively low, pairing eggplant with complementary plant-based proteins (e.g., legumes, soy, or quinoa) could enhance its nutritional profile Tachie, et al 2023. Eggplant-based meat substitutes can be optimized for improved nutritional outcomes through fortification strategies, such as incorporating plant-based protein isolates or vitamin enrichment.

Promotion of eggplant as a meat substitute fits into world environmental objectives. Eggplant growing uses less land and water and produces much fewer greenhouse gas emissions than livestock production. Optimizing eggplant cultivation techniques could assist to build more sustainable food systems and maybe increase the feasibility of eggplant as a meat substitute, as Zhang et al. (2022) suggest. Encouragement of eggplant farming is a good way to help local food security and lower reliance on imported substitutes given the rising climate change issues in the Philippines (Jonveaux, 2024; Monsod et al., 2021; Pereira & Shaw, 2021). The 2022 Wijerathna-Yapa and Pathirana underline the need of sustainable food systems for adaptation to climate change. Local eggplant farming lessens the environmental damage caused by food transportation over great distances. Emerging technologies have the potential to increase the resilience of plant-based food production under climate change, according to Mešić et al. (2024). By choosing heat-tolerant genotypes and water-efficient irrigation, among other climate-smart agricultural techniques, eggplant cultivation in the Philippines improves the food supply's resistance to climate-related disturbances. Encouragement of eggplant farming increases food stability in the Philippines and helps to build climate resilience.

Changing the bigger economic worth of eggplant farming stressed by Oladosu et al. (2021), eggplant-based meat substitutes may help local farmers in the Philippines thrive financially. The study notes that eggplant is a crop with enormous economic importance all around and that by increasing its resistance

and output, varietal evolution can significantly influence farmer incomes. Strengthening local production and value-added processing of eggplant can create employment opportunities within the agricultural and food manufacturing sectors. Furthermore, developing cost-effective, nutritious meat alternatives addresses food affordability concerns for low-income populations.

Composition and production of meat substitutes made from eggplant need to be carefully looked at in terms of methods for changing the texture. Eggplant nuggets' structural integrity can be improved and they will thus more closely resemble conventional meat products by binding agents, hydrocolloids, and texturizing techniques including extrusion heating or fermentation. Moreover, commercial success largely depends on maximizing storage conditions and guaranteeing shelf-life stability by creative packaging methods. Various cooking techniques, such air fried or vacuum dehydrated serve to improve the sensory appeal and nutritional retention of eggplant-based goods.

Eggplant is already preferred in vegetarian and vegan diets for its texture, flexibility, and creation of a desired umami taste when cooking (Kittler, 2016.). Since flesh is naturally able to imitate its texture and weight, it is a great competitor for meat replacement in many different cooking applications. Umami develops in direct line with the synthesis of specific chemicals as one cooks. Improved knowledge of the interconnections of cooking methods, seasoning, and umami development in eggplant nuggets could greatly increase product acceptability.

This research delves at the technological development and sensory acceptability of eggplant nuggets as a meat alternative. The major objectives were to develop nugget products with several degrees of eggplant inclusion, then evaluate their sensory attributes (color, fragrance, texture, and taste) with semantic scales. The study also examines how overall acceptance and sensory impressions change with panelist age and gender. This project aims to add to the already rising body of knowledge on plant-based meat alternatives while meeting the growing consumer demand for healthier and more sustainable food options and improving local food security and the livelihoods of Filipino farmers. This study acknowledges that its findings would be best appropriate in the socioeconomic setting of the Philippines, where fairly priced nutrition and agricultural support take front stage.

2. Materials and Methods

2.1 Experimental Design

Four nuggets treatment were prepared differently according to the ratio and proportion of meat and plant-based ingredient but no difference in the usage of the new developed marinade premixes (as shown in Table 1) and one reference were evaluated by panel.

All the experiments were repeated twice. Each panel was requested to evaluate four treatment sample and the control sample in one session. Each treatment was assigned with unique number code for identification purposes.

Table 1. Eggplant nuggets formulation

Ingredients	T1	T2	T3	T4
Chicken Meat	75%	50%	25%	0%
Egg plant	25%	50%	75%	100%
All Purpose Flour	0.016	0.016	0.016	0.016
Chilled water	0.042	0.042	0.042	0.042
Refined sugar	0.001	0.001	0.001	0.001

Skimmed milk	0.017	0.017	0.017	0.017
Nuggets Mix	0.026	0.026	0.026	0.026
Onion Powder	0.001	0.001	0.001	0.001
Garlic powder	0.001	0.001	0.001	0.001
Tari SLE	0.005	0.005	0.005	0.005
Iodized Salt	0.003	0.003	0.003	0.003
STPP	0.0010	0.0010	0.0010	0.0010
Chilled Water	0.077	0.077	0.077	0.077
White Pepper	0.005	0.005	0.005	0.005
Chilled water	0.038	0.038	0.038	0.038
TVP/PBP	0.060	0.060	0.060	0.060
Chilled water	0.017	0.017	0.017	0.017
Fat replacer	0.130	0.130	0.130	0.130

Note: Control: 100% meat of raw material weight. Marinade blend is 12.5% of the total population

The marinade contains various important ingredients, each with a specific percentage and weight. Iodized salt forms 1.210% of the marinade, having a weight of 0.003 kg. Monosodium glutamate (MSG) is present at 0.403%, with a weight of 0.001 kg. Sodium tripolyphosphate (STPP) also forms 0.403% of the marinade, equally weighing 0.001 kg. White pepper is at 1.210%, equaling the percentage of iodized salt, and equally weighs 0.003 kg. Both the onion powder and the garlic powder are present at 0.403%, with each weighing 0.001 kg. The starch is the greatest component at 8.468% of the marinade and weighing 0.021 kg. The mixture brings a smooth mixture of flavor and preservatives in the marinade.

2.2. Preparation of Food Samples

The process of nuggets preparation are as follows: Boiling of egg plant. Peeling off the skin of egg plant. Weighing of ingredients. Grinding of meat and egg plant separately using 3mm mesh size for uniformity of particle size. Mixing of Meat, egg plant and all ingredient using a mixer paddle at speed 3 for 90 seconds. Packed in 7 x 14: x70 microns thick clear plastic. Flattened to make the block uniform in height. Removed air bubbles. Freeze. Manually mold the nuggets into desired shape (making sure that gram per piece is within 13-15 grams as standard set). Predust 1 kilo nuggets using 200 grams pre-dust. Sprinkle the nuggets then shake to removed excess pre dust. Batter-coated (1 part dry to 1.5 water dilution) using 200g dry batter diluted to 300 g chilled water. Dip nuggets for 10 seconds and removed excess batter. Roll into breadcrumb, making sure that all parts were fully coated. Par-fried/Flash frying of chicken nuggets in vegetable fat at 178°C for approximately 60 seconds, Freeze and packed into 6 x 10 for 200g. Stored at – 18 °C. On the day of sensory evaluation, chicken until was pre-fried in vegetable oil fat at 178C for 4 minutes until an internal temperature of 80°C was reached.

2.3 Sensory Evaluation

A descriptive testing method was employed to characterize the sensory attributes of each treatment and to assess the acceptability of chicken nuggets incorporating plant-based ingredients. Thirty panelists were recruited (primarily business owners, sales representatives, government employees, vendors, couriers, teachers, and students). The panelists' ages ranged from 13 to 54, with an equal number of males and females participating. Before each session, panelists received a briefing on the evaluation procedure. Sensory evaluations of the chicken nuggets with meat substitutes were conducted in-home across various locations. Each panelist was assigned a unique identification number and tasked with

evaluating all samples. Panelists used a score sheet to rate each sample (excluding the control) on color, texture, aroma, and flavor using a 9-point Hedonic scale. Additionally, panelists voluntarily provided demographic information, including gender and age, on the score sheet. Semantic scale was used to evaluate sensory characteristics of eggplant nuggets.

3. RESULTS AND DISCUSSION

1. Sensory Characteristics of the Developed Products

Table 2. Sensory Characteristics of the Developed Products

Sensory Characteristics	M	SD	Descriptive Interpretation
Color			
100% Eggplant	3.97	0.81	Pronounced color
75% Eggplant and 25% Meat	4.00	0.83	Pronounced color
50% Eggplant and 50% Meat	4.13	0.82	Pronounced color
25% Eggplant and 75% Meat	3.87	0.90	Pronounced color
Aroma			
100% Eggplant	4.13	0.82	Pronounced aroma
75% Eggplant and 25% Meat	4.17	0.75	Pronounced aroma
50% Eggplant and 50% Meat	4.23	0.73	Pronounced aroma
25% Eggplant and 75% Meat	4.03	0.81	Pronounced aroma
Texture			
100% Eggplant	4.27	0.64	Moderately juicy
75% Eggplant and 25% Meat	4.13	0.73	Moderately juicy
50% Eggplant and 50% Meat	4.13	0.82	Moderately juicy
25% Eggplant and 75% Meat	4.10	0.76	Moderately juicy
Taste			
100% Eggplant	4.30	0.75	Pronounced taste and flavor
75% Eggplant and 25% Meat	4.20	0.76	Pronounced taste and flavor
50% Eggplant and 50% Meat	4.13	0.78	Pronounced taste and flavor
25% Eggplant and 75% Meat	4.13	0.78	Pronounced taste and flavor
Overall			
100% Eggplant	4.17	0.62	Pronounced eggplant nuggets
75% Eggplant and 25% Meat	4.13	0.59	Pronounced eggplant nuggets
50% Eggplant and 50% Meat	4.16	0.64	Pronounced eggplant nuggets
25% Eggplant and 75% Meat	4.03	0.67	Pronounced eggplant nuggets

Table 5 shows that in terms of color all treatments were perceived to be “Pronounced color”. However, among the four treatments, treatment 3 has the highest mean of 4.13. This result means that the color of treatment 3 is most preferred by the panelists. In terms of aroma, all treatments were perceived to have

"Pronounced eggplant nuggets aroma". However, among the treatments, treatment 3 has the highest mean followed by treatment 2 with a mean score of 4.17 which means that the aroma of treatments 3 is most preferred by the panelists.

In terms of texture, all treatments were perceived to have "moderately juicy" texture. However, treatment 1 has the highest mean of 4.27 which means that the texture of treatment 1 is most preferred by the panelists.

Lastly, in terms of the taste, treatment 1 were perceived to have "Pronounced eggplant nuggets taste and flavor". Further, treatment 2 and 3 has the mean rating of 4.13. However, treatment 1 has the highest mean rating of 4.30 which means that the taste of treatment 1 is most preferred by the panelists. The above findings only imply that treatment 1 replace by 100% eggplant is most preferred by the panelists in terms of the sensory attributes of the developed eggplant nuggets. However, as to color and aroma, treatment 3 is most preferred and as to texture and taste, treatment 1 is most preferred by the panelists.

Furthermore, the present finding confirms the research finding of Kumar, et al., (2022) that when animal-derived proteins are unable to meet the demands of the world's population, the use of plant proteins will become crucial. This was agreed by the study conducted by Detzel, et al., (2022), in which he discussed that the improved environmental footprints of plant-based foods are clearly possible.

Based on the findings of Bunmee et al.'s (2022) study, he discussed that purple eggplant flour has the potential to be used as an ingredient as a fat replacer, antioxidant, and fiber enhancer. He stated the optimum content of eggplant flour to maintain its visual appearance, juiciness, hardness, and flavor. Thus, these findings revealed that eggplant as a meat substitute helps enhance the sensory characteristics of nuggets, which is evident in the rating of the panel.

2. Mean Rating Comparison on the Sensory Characteristics of the Developed Eggplant Nuggets

2.1 Mean Rating Comparison on the Sensory Characteristics of the Developed Eggplant Nuggets In Terms of Age

The result shows that the panelists, whose ages range from late middle age (45 to 64), rated the color of the developed products the highest mean rating of 3.67(SD=0.58), describing it as "pronounced color of eggplant nuggets". This indicates that the group that preferred the color of the developed product the most was in the late Middle Ages. Significant test using Anova reveals that there is no significant difference on the perception of the panelists in terms of the color of the developed eggplant nuggets.

In terms of aroma, the mean rating of Late Adolescents (18-21) group perceived the highest mean rating of 4.80 (SD=0.45) which indicate a "Very Pronounced eggplant nuggets aroma". This denotes that the aroma is most preferred by Late Adolescents (18-21) group. This finding only implies that there is no significant difference in panelists' perceptions of the aroma of the developed eggplant nuggets when grouped by age.

The texture of the developed product received the highest mean rating of 4.40 (SD = 0.55) from the Late Adolescents (18-21) group, indicating a "moderately juicy" texture. This demonstrates that the texture of the developed product is preferred by the Late Adolescents (18-21) group the most. However, the mean rating of the other age group shows that there is no significant difference in the panelists' perception of the texture of the developed eggplant nuggets when grouped by age.

Lastly, in terms of taste, Late Adolescents (18-21) group perceived the highest mean rating of 4.70 (SD=0.45) which indicate a "Very pronounced eggplant nuggets taste and flavor". This indicates that the developed product's taste and flavor are most preferred by the Late Adolescents (18-21) group. The

findings also show that there is no significant difference in taste perception among panelists when grouped by age.

Late Adolescents (18-21) appeared to have the highest mean rating of 4.63(SD=0.33) on the sensory characteristics of the developed eggplant nuggets, indicating that the products developed were most preferred by this age group. However, the findings revealed that the all group preferred the developed product. This implies that there is no significant difference on the perception as to age group.

2.2 Mean Rating Comparison on the Sensory Characteristics of the Developed Eggplant Nuggets In Terms of Gender

The results present the sensory evaluation of the panelist on the sensory characteristics of the developed product in terms of gender. In terms of color, male has a higher rating as compared to female with a mean rating of 3.31 (SD=0.48) and 2.94 (SD=0.75) consecutively. This notes that the color of the developed product is more preferred by male than female with a "Slightly pronounced color of eggplant nuggets" description.

As to the aroma, both males and females have a close mean rating of 4.18 and 4.15, respectively, with a "pronounced eggplant nuggets aroma" description. This means that the aroma is more preferred by females than males.

In terms of texture, both males and females rated the developed product as moderately juicy, with mean ratings of 4.24 and 4.08, respectively. This indicates that the texture of the developed eggplant nuggets is more preferred by females.

In terms of taste, both males and females perceived the taste of the developed product "pronounced eggplant nuggets' taste and flavor." However, females have a higher rating than males, with a mean of 4.24 and 4.13, respectively. This shows that the taste of the developed product is more preferred by the female panelists.

Lastly, the overall sensory characteristics of the developed eggplant nuggets were most preferred by both male and female panelists. This indicates that there is no significant difference in sensory characteristics according to gender.

3. Acceptability of the Developed Eggplant Nuggets

Table 3. Acceptability of the Developed Eggplant Nuggets

Proportion of Plant-based Extenders	M	SD	Descriptive Interpretation
100% Eggplant	7.53	1.01	Like very much
75% Eggplant and 25% Meat	7.57	1.14	Like very much
50% Eggplant and 50% Meat	7.47	1.11	Like very much
25% Eggplant and 75% Meat	7.57	1.14	Like very much

For the overall acceptability of eggplant nuggets, a 9-point Hedonic Scale was used. Table 3 above shows that all the 4 treatment has an overall acceptability of "Like very much". However, treatment 2 and 4 has the highest mean rating of 7.57 with a qualitative description of "Like very much". On the other hand, treatment 1 has a mean rating of 7.53 and treatment 3 has a mean rating of 7.47. This denotes that all treatment is acceptable by the panelist regardless of eggplant proportioned as substitute to meat content of the chicken nuggets.

4. Mean Rating Comparison on the Acceptability of the Developed Eggplant Nuggets in terms of Age

Table 4. Comparison on the Acceptability of the Developed Eggplant Nuggets

Sensory Characteristics		M	SD	F	p
100% Eggplant	Early Adolescence (10-13)	6.50	2.12	2.60	0.051
	Middle Adolescence (14-17)	6.50	0.71		
	Late Adolescents (18-21)		0.55		
	Early Adulthood (22-34)		0.94		
	Early Middle Ages (34-44)	7.25	0.50		
	Late Middle Ages (45-64)	7.67	0.58		
75% Eggplant and 25% Meat	Early Adolescence (10-13)	8.50	0.71	0.60	0.70
	Middle Adolescence (14-17)	7.00	1.41		
	Late Adolescents (18-21)	7.40	1.34		
	Early Adulthood (22-34)	7.71	1.33		
	Early Middle Ages (34-44)	7.00	0.00		
	Late Middle Ages (45-64)	7.67	0.58		
50% Eggplant and 50% Meat	Early Adolescence (10-13)	7.00	2.83	0.49	0.78
	Middle Adolescence (14-17)	6.50	0.71		
	Late Adolescents (18-21)	7.60	1.52		
	Early Adulthood (22-34)	7.50	0.94		
	Early Middle Ages (34-44)	7.50	0.58		
	Late Middle Ages (45-64)	8.00	1.00		
25% Eggplant and 75% Meat	Early Adolescence (10-13)	8.50	0.71	0.69	0.64
	Middle Adolescence (14-17)	6.50	0.71		
	Late Adolescents (18-21)	7.60	1.52		
	Early Adulthood (22-34)	7.50	1.22		
	Early Middle Ages (34-44)	7.50	0.58		
	Late Middle Ages (45-64)	8.00	1.00		

Note: $p < 0.05$

As shown in table 4, analysis of variance for the overall acceptability using a 9 point Hedonic Scale shows that there is no significant difference on the perception of the panelists when grouped according to age. This simply implies that the overall acceptability of the developed eggplant nuggets does not varies between different treatments.

Table 6. Acceptability of the Developed Food Products on the Different Treatments in terms of Gender

Treatment		M	SD	t	p
100% Eggplant	Male	7.38	1.12	-0.70	0.49
	Female	7.65	0.93		
75% Eggplant and 25% Meat	Male	8.00	0.71	2.06	0.50
	Female	7.24	1.30		

50% Eggplant and 50% Meat	Male	7.54	1.13	0.31	0.76
	Female	7.41	1.12		
25% Eggplant and 75% Meat	Male	7.69	0.70	0.52	0.61
	Female	7.47	1.28		

Note: $p < 0.05$

The table shows the acceptability of the developed products for the different treatments in terms of gender. The findings revealed that male panelists rated treatments 2, 3, and 4 higher than female panelists. However, treatment 1 was given a higher rating by the female panelists compared to the males. This indicates that when compared in terms of gender, it appears that there is no significant difference in the acceptability of the developed eggplant nuggets.

Conclusion

The use of meat substitutes reduces the negative effects of livestock on the environment and human health. Due to these negative effects, consumers are switching to meat substitutes or goods made with fewer negative externalities than customary goods. Plant-based meat substitutes have been developed to meet rising consumer demand and ensure future food security. In terms of protein, fat, and other key nutrients, they are nutritionally equivalent to animal-based meats. The study have shown that the developed eggplant nuggets has a comparable sensory characteristics as the control which does not contain any eggplant as ingredients. The findings also indicate that, as to age and gender, the panel's perception of the sensory characteristics of the developed eggplant nuggets shows no significant difference. The study found that the development of Eggplant Nuggets was acceptable to its potential consumers. The study found that all treatments, consisting of varying proportions of plant-based ingredients, were both acceptable to consumers in terms of sensory level.

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