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Jophil Thomas
M.V.Sc. Scholar, Department
of Livestock Products
Technology, CVAS, Mannuthy,
Thrissur, Kerala, India

Irshad A
Assistant Professor,
Department of Livestock
Products Technology, CVAS,
Mannuthy, Thrissur, Kerala,
India

Adithya AA
Research Scholar, Department
of Livestock Products
Technology, CVAS, Mannuthy,
Thrissur, Kerala, India

Sathu T
Professor, Department of
Livestock Products
Technology, CVAS, Mannuthy,
Thrissur, Kerala, India

Vasudevan VN
Professor and Head,
Department of Livestock
Products Technology, CVAS,
Mannuthy, Thrissur, Kerala,
India

Silpa Sasi
Assistant Professor,
Department of Livestock
Products Technology, CVAS
Mannuthy, Thrissur, Kerala,
India

Corresponding Author:
Jophil Thomas
M.V.Sc. Scholar, Department
of Livestock Products
Technology, CVAS, Mannuthy,
Thrissur, Kerala, India

Valorization of pork by-products: Development of a plant-enriched pork skin pickle

Jophil Thomas, Irshad A, Adithya AA, Sathu T, Vasudevan VN and Silpa Sasi

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Abstract

Pork rinds, derived from pig skin, offer a unique, low-carbohydrate and high-protein snack option. Pickled pork skins are popular across diverse culinary traditions due to their appealing flavour and nutritional advantages, as well as their shelf stability, which lends strong market potential. This study developed a value-added pork skin pickle incorporating mango (*Mangifera indica*) and elephant foot yam (*Amorphophallus paeoniifolius*) to enhance both sensory quality and nutritional value. Four experimental formulations were prepared: M1 (30% pork skin and 15% mango) and M2 (40% pork skin and 13% mango) and E1 (30% pork skin and 15% elephant foot yam) and E2 (40% pork skin and 13% elephant foot yam) and were stored in glass jars at ambient temperature and evaluated for physicochemical properties, microbial load and sensory attributes. While the pH levels increased over time, the yeast and mould counts remained within acceptable limits, ensuring product stability. Sensory analysis revealed the most preferred formulation to be the one containing 30% pork skin with 15% elephant foot yam, offering 16.6% protein, 2.65 mg crude fibre, 3.45% total ash, and 284.52 kcal/100g. The absence of spoilage during storage further confirmed the product's stability and safety, highlighting its potential as a value-added meat snack with enhanced sensory appeal.

Keywords: Meat pickle, value addition, pork skin, pork-byproduct, elephant foot yam and sensory evaluation

Introduction

Meat has long been a fundamental part of the human diet, providing high-quality protein, essential amino acids and key micronutrients (Lawrie and Ledward, 2006) [9]. Among different types of meat, pork is one of the most widely consumed, valued for its taste, versatility, and nutritional benefits. While traditionally consumed in fresh or cured forms, innovative processing methods have expanded its culinary applications, one of which is pickling.

Pork rind, derived from pig skin, is commonly used to produce crispy snacks but also has potential as a pickled delicacy. Pickling enhances its flavour, extends shelf life and creates a ready-to-eat product with significant market potential. This study focuses on the development and quality evaluation of pork rind pickles incorporating mango and elephant foot yam, assessing their physico-chemical, sensory and microbiological characteristics. By optimizing ingredient levels and storage stability, this research aims to introduce a value-added, nutritious meat-based pickle to the market.

Materials and Methods

Preparation of Pork Rind Pickle with Mango and Elephant Foot Yam

The preparation process began with roasting mustard seeds until they crackled, followed by roasting fenugreek seeds until they turned darker and released an aroma. Both were cooled and ground separately into fine powders. Fresh vegetables, including green chilies, garlic and ginger, were uniformly chopped and weighed. Pig skin was boiled with garlic, ginger, pepper powder, salt and turmeric in a closed chamber, then cut into pieces similar in size to the vegetables.

The prepared pig skin and vegetables were combined in a bowl, followed by the addition of ground mustard and fenugreek powders, chili powders, salt, vinegar and oil in specified

proportions. A tempering mix of hot oil, mustard seeds, split red chilies and asafoetida was added for enhanced flavour. For mango-incorporated pickle, blanched mango pieces were added to the mixture. For elephant foot yam-incorporated pickle, boiled and shallow-fried yam pieces were used. The final products were weighed, stored in glass jars at room temperature and evaluated for chemical, microbiological and sensory qualities at seven-day intervals up to 28 days.

Table 1: Formulation of pork rind pickle incorporated with mango and elephant foot yam

Ingredients (%)	M1	M2	E1	E2
Pork skin	30	40	30	40
Mango	15	13	-	-
Elephant foot yam	-	-	15	13
Carrot	15	13	15	13
Garlic	3	2.5	3	2.5
Ginger	1	1	1	1
Green chilly	2	2	2	2
Salt	1.5	1.5	1.5	1.5
Fenugreek powder	0.5	0.5	0.5	0.5
Mustard powder	0.5	0.5	0.5	0.5
Kashmiri chilly powder	0.5	0.5	0.5	0.5
Vinegar	11	9	11	9
Chilli powder	2	2	2	2
Oil	5	5	5	5

Product yield

The cooking yield percentage is determined by measuring the weight of the prepared pickle, multiplying it by 100 and then dividing the result by the pickle's initial weight before preparation.

pH

The estimation of pH of pickle was measured using a digital pH meter in accordance with AOAC (2016) [1]. About 10g of pickle was homogenized in a homogenizer with 50 ml of distilled water for about one minute. The pH was recorded by immersing the combined glass electrode of digital pH meter in the homogenate.

Proximate composition

The proximate composition, including moisture, crude protein, ether extract, crude fibre and total ash, of pork skin pickle was determined using the methods recommended by AOAC (2016) [1].

Yeast and mould

The yeast and mould count per gram of the sample was estimated using the method outlined by Beuchat and Cousin (2001) [2]. Sabouraud's Dextrose Agar (HiMedia, Mumbai) served as the culture medium and the plates were incubated at 25-27 °C for three days. The results were recorded as log10 CFU/g.

Sensory evaluation

A semi-trained panel of seven members from the Department of Livestock Products Technology at the College of Veterinary and Animal Sciences, Mannuthy, Thrissur, conducted the sensory evaluation using an eight-point Hedonic scale. Samples were evaluated for appearance, flavour, texture, juiciness, and over all acceptability using 8-point hedonic scale.

Statistical analysis

The physicochemical, proximate, and sensory characteristics of pork rind pickle were analysed using SPSS software (version 24.0), following the guidelines of Snedecor and Cochran (1994) [15].

Results and Discussion

The study aimed to develop and evaluate the quality of pork skin pickle incorporated with mango and elephant foot yam. The products were stored at room temperature and analysed for physicochemical, sensory and microbiological characteristics at regular intervals over 28 days.

Product yield

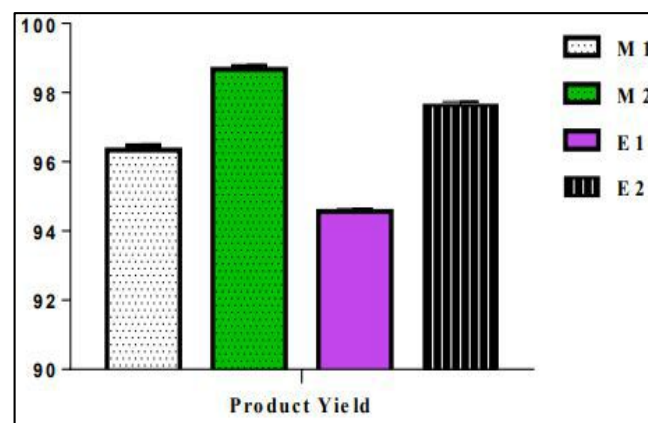


Fig 1: Product yield

The highest product yield ($p < 0.05$) was observed in the M2 formulation, while the lowest was recorded in E1, suggesting that a greater proportion of pork skin positively influenced the overall yield. These findings align with Choe *et al.* (2009) [3], who noted that incorporating pork skin significantly enhanced the cooking yield of sausages.

pH

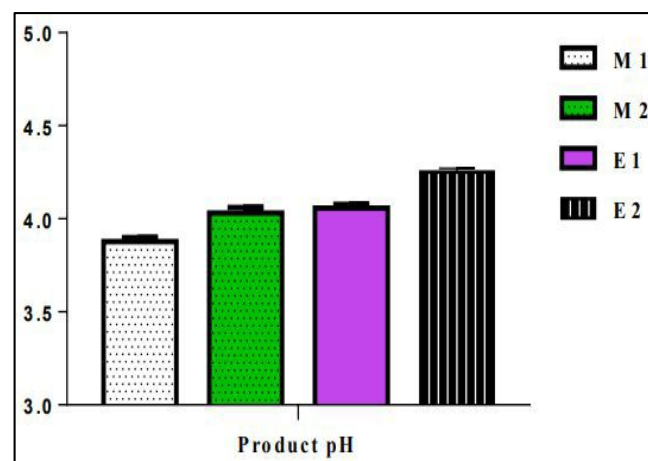


Fig 3: Product pH

Significant differences ($p < 0.05$) were observed among the treatment groups. The pH values of the samples ranged from 3.88 ± 0.02 to 4.25 ± 0.02 , all falling below the critical threshold of 4.6, adequate to inhibit the growth of most harmful bacteria. According to Rokka (2013) [12], pickling is an effective preservation method capable of extending shelf life for several months. This preservation is primarily

achieved through reduced moisture content and lowered pH, both of which are essential for the stability of pickled products. Acidification to a pH of 4.6 or lower prevents the germination and toxin production of *Clostridium botulinum* spores, making the food microbiologically safe (VanGarde and Woodburn, 1999) [16]. The observed decrease in pH is

attributed to the addition of vinegar, which act as key preservative agents. Beyond preservation, pickling also enhances sensory attributes such as flavour and taste, contributing to overall product appeal (Das *et al.*, 2007) [5].

Proximate composition

Table 2: Proximate composition

Proximate Analysis Parameters	M1	M2	E1	E2
Moisture (%)	53.58±0.21 ^b	52.13±0.13 ^a	52.56±0.35 ^a	55.98±0.37 ^c
Protein (%)	10.97±0.16 ^a	16.97±0.29 ^c	16.61±0.19 ^c	15.77±0.09 ^b
Fat (%)	20.88±0.38 ^b	19.37±0.37 ^a	21.72±0.31 ^b	19.57±0.17 ^a
Ash (%)	2.71±0.01 ^b	2.55±0.05 ^a	3.45±0.02 ^d	2.89±0.04 ^c
NFE (%)	11.87±0.66 ^c	8.98±0.53 ^b	5.65±0.56 ^a	5.79±0.59 ^a
Energy value (Kcal/100 g)	279.28±1.61 ^b	278.10±2.41 ^b	284.52±2.37 ^b	262.37±0.76 ^a
Crude fibre content (mg)	2.42±0.04 ^b	1.36±0.02 ^a	2.65±0.02 ^c	1.45±0.11 ^a

Significant at 0.05 level; ** Significant at 0.01 level; ns-non-significant at 0.05 level. Means with different superscripts in rows differ significantly.

Proximate composition analysis showed significant differences ($p < 0.05$) in moisture, protein, fat, ash and crude fibre contents across the various treatments. Moisture content was found to be highest in the E2 formulation and lowest in M2, while protein levels peaked in M2 and were lowest in M1. Fat content was greatest in E1 and lowest in M2. These findings align with Choe *et al.* (2016) [14], who reported that incorporating swollen pig skin along with natural vinegars increased moisture levels while reducing fat and protein content in blood sausages. Pork rinds are naturally rich in protein and fat and contain no carbohydrates, making them an attractive option for low-carb diets.

Ash content, energy value, and crude fibre were most elevated in the E1 formulation. This may be attributed to the nutritional profile of elephant foot yam (EFY), which is rich in dietary fibre, carbohydrates, glucose, protein, sugars, and key minerals such as calcium, sodium, potassium, and vitamin C (Sheela Immanuel *et al.*, 2020) [14]. Tubers like EFY are valued for their caloric content and are widely consumed as energy-dense foods (Santosa *et al.*, 2014) [13]. However, EFY is relatively low in protein, with Peetabas *et al.* (2015) [10] noting its limited protein concentration. Despite their modest protein content, EFY tubers are highly nutritious and can contribute significantly to daily mineral intake. Essential minerals like phosphorus and calcium play vital roles in bone development, enzyme function, acid-base balance, and muscle activity (Jogi and Lahre, 2020) [17].

Sensory evaluation

Table 3: Sensory evaluation

Sensory Attributes	M1	M2	E1	E2
General appearance	7.00±0.15	6.93±0.20	6.93±0.20	7.07±0.13
Flavour	6.79±0.24	6.43±0.31	6.57±0.19	6.79±0.21
Texture	6.93±0.16	6.79±0.18	6.86±0.17	6.86±0.17
Juiciness	6.93±0.27	6.86±0.28	6.64±0.37	6.86±0.28
Overall acceptability	6.71±0.26	6.82±0.21	6.89±0.20	6.86±0.23

* Significant at 0.05 level; ** Significant at 0.01 level; ns-non-significant at 0.05 level. Means with different superscripts in rows differ significantly.

No significant differences ($p > 0.05$) were observed among the treatments in terms of appearance, flavour, texture, juiciness and overall acceptability. Sensory analysis indicated that the E1 formulation (30% pork skin and 15%

elephant foot yam) received the highest overall acceptability score, followed closely by M1. These findings align with those of Choe *et al.* (2009) [3], who reported that incorporating pork skin enhanced the quality attributes of liver sausages. Similar results were also observed by de Oliveira Fagundes *et al.* (2017) [16] in pork skin-enriched burgers.

Storage study pH

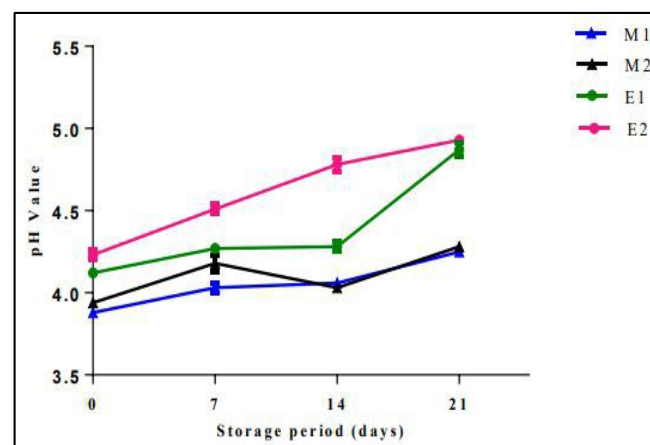


Fig 4: Effect of storage days on pH of pickles

A significant ($p < 0.05$) increase in pH was observed across all treatments over the storage period, with the E2 formulation exhibiting the highest pH and M1 showing the lowest. According to Rokka (2013) [12], the pH of pork pickle remains relatively stable, with only minimal increases noted even after 150 days of storage. In a study on pickled chicken meat, Reddy *et al.* (1997) [11] attributed the sustained low pH during storage to the preservative effects of mustard oil, citric acid and vinegar, which also played a significant role in inhibiting microbial growth. Similarly, Kumar and Bachhil (1993) [8] reported that in pork pickle, factors such as reduced moisture content, lower microbial load and the antimicrobial properties of vinegar and spices contributed effectively to the product's extended shelf life.

Yeast and mould count

Microbiological analysis showed that although yeast and mold counts increased over time, they stayed within

acceptable limits during the storage period. Rokka (2013)^[12] suggested that the reduction in microbial load could be due to the preservative effects of the low pH from vinegar, along with the low moisture content and the antimicrobial properties of the spices. Furthermore, mustard oil was found to inhibit the growth of yeast and moulds.

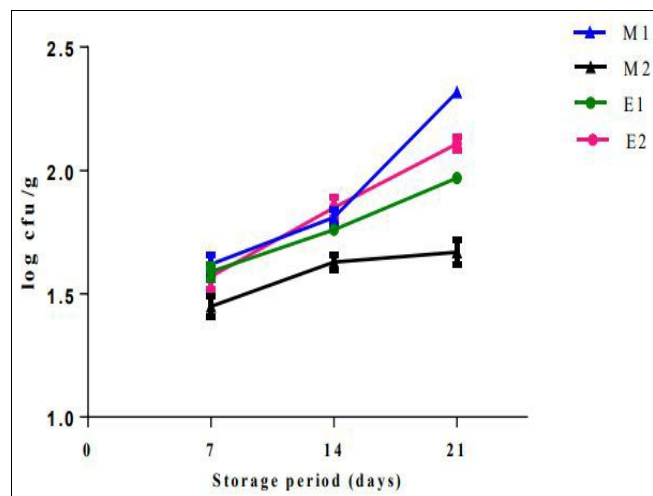


Fig 5: Effect of storage days on yeast and mould of pickles

Sensory evaluation

The sensory evaluation indicated that there were no significant ($p>0.05$) changes in appearance, flavour, texture, juiciness and overall acceptability of the treatment samples throughout the storage period. This suggests that the inclusion of pork skin did not negatively impact the sensory quality of the pickle. Similarly, Rokka (2013)^[12] found no significant differences in appearance and overall acceptability between chicken and pork pickle samples during storage.

Table 4: Effect of storage days on sensory attributes of pickles

General appearance				
Treatments	0	7	14	21
M1	7.00±0.15	7.07±0.17	6.79±0.15	6.29±0.42
M2	6.93±0.20	7.07±0.17	6.36±0.28	6.29±0.42
E1	6.93±0.20	7.00±0.22	6.43±0.30	6.93±0.32
E2	7.07±0.13	7.07±0.17	6.32±0.27	6.57±0.30
Flavour				
Treatments	0	7	14	21
M1	6.79±0.24	6.75±0.22	5.75±0.31	6.14±0.46
M2	6.43±0.31	6.43±0.41	6.36±0.33	5.86±0.28
E1	6.57±0.19	6.96±0.09	6.29±0.49	6.43±0.37
E2	6.79±0.21	6.64±0.18	4.43±0.48	6.21±0.29
Texture				
Treatments	0	7	14	21
M1	6.93±0.16	6.89±0.15	5.86±0.14	6.21±0.32
M2	6.79±0.18	6.54±0.30	6.07±0.34	5.86±0.26
E1	6.86±0.17	6.93±0.07	6.36±0.28	6.50±0.33
E2	6.86±0.17	6.64±0.18	5.50±0.39	6.00±0.32
Juiciness				
Treatments	0	7	14	21
M1	6.93±0.27	7.04±0.11	5.50±0.29	6.07±0.35
M2	6.86±0.28	6.64±0.18	6.14±0.18	6.07±0.30
E1	6.64±0.37	6.54±0.30	5.93±0.35	6.86±0.28
E2	6.86±0.28	6.46±0.42	5.07±0.41	6.86±0.28
Overall acceptability				
Treatments	0	7	14	21
M1	6.71±0.26	7.00±0.12	5.75±0.38	6.21±0.43
M2	6.82±0.21	6.79±0.15	6.21±0.26	5.93±0.32
E1	6.89±0.20	7.00±0.11	5.93±0.68	6.64±0.28
E2	6.86±0.23	6.71±0.18	4.57±0.61	6.64±0.30

* Significant at 0.05 level; ** Significant at 0.01 level; ns-non-significant at 0.05 level. Means with different superscripts in rows differ significantly.

Cost of production

Table 5: Cost of production

	M1		M2		E1		E2	
Ingredients	Quantity (Kg)	Cost (Rs)	Quantity (Kg)	Cost (Rs)	Quantity (Kg)	Cost (Rs)	Quantity (Kg)	Cost (Rs)
Carrot	0.05	3	0.05	3	0.05	3	0.05	3
Mango	0.05	2.5	0.05	2.5				
Elephant foot yam					0.05	2	0.05	2
Pork skin	0.105	8.4	0.18	14.4	0.105	8.4	0.18	14.4
Garlic	0.019	3.8	0.019	3.8	0.019	3.8	0.019	3.8
Ginger	0.006	6	0.006	6	0.006	6	0.006	6
Salt	0.0082	0.098	0.0082	0.098	0.0082	0.098	0.0082	0.098
Oil	0.038	7.6	0.038	7.6	0.038	7.6	0.038	7.6
Turmeric powder	0.0002	0.04	0.0002	0.04	0.0002	0.04	0.0002	0.04
Pepper powder	0.003	2.4	0.003	2.4	0.003	2.4	0.003	2.4
Green chilly	0.005	0.25	0.005	0.25	0.005	0.25	0.005	0.25
Mustard	0.0018	0.36	0.0018	0.36	0.0018	0.36	0.0018	0.36
Fenugreek	0.0018	0.45	0.0018	0.45	0.0018	0.45	0.0018	0.45
Chilly powder	0.007	1.89	0.007	1.89	0.007	1.89	0.007	1.89
Vinegar	0.035	2.24	0.035	2.24	0.035	2.24	0.035	2.24
Kashmiri chilly	0.00125	0.437	0.00125	0.437	0.0012	0.437	0.00125	0.437
Asafoetida	0.00175	1.66	0.00175	1.66	0.0017	1.66	0.00175	1.66
Red chilly	0.007	1.47	0.007	1.47	0.007	1.47	0.007	1.47
Mustard seed	0.01	2	0.01	2	0.01	2	0.01	2
Total cost (Rs)		39.09		45.09		39.09		45.09
Yield (Kg)	0.35		0.425		0.35		0.425	
Cost/kg pickle (Rs)		112		106		112		106

The production costs for M1, M2, E1 and E2 pickles were ₹112, ₹106, ₹112 and ₹106 per kg, respectively. In comparison, the direct material costs for chicken meat and

pork pickles were reported to be ₹277.86 and ₹417.86 per kg of the finished product, respectively, as per Rokka (2013)^[12].

Conclusion

The development of pork skin pickle incorporating mango and elephant foot yam successfully resulted in a value-added meat product with improved sensory appeal. Among the different formulations, the E1 treatment, containing 30% pork skin and 15% elephant foot yam, was the most preferred due to its balanced nutritional profile, including 16.6% protein, 2.65 mg crude fibre, 3.45% total ash and 284.52 kcal/100g of energy. The product's shelf stability was enhanced by a low microbiological load, the low pH from vinegar and the antimicrobial and preservative effects of spices and condiments. It remained stable and free from spoilage for up to 28 days at room temperature, maintaining its sensory qualities and showing no significant microbial deterioration. This study highlights the potential of pork skin pickle as a nutritious, shelf-stable and commercially viable value-added meat product.

Statements

The authors declare that they have no financial interests that are directly or indirectly related to the work submitted for publication.

Declarations

This study didn't receive any fund.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

Ethical Statement

Participation in the sensory evaluation was voluntary, conducted under ethical guidelines and posed no risk or harm to participants. Therefore, no human rights violations occurred during the conduct of research.

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