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The effect of pineapple peel and chicken bone flours on the physicochemical properties and sensory acceptability of noodles

Pengaruh tepung kulit nanas dan tepung tulang ayam terhadap sifat fisikokimia dan penerimaan sensorik mie

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Abstract

Wheat has limited nutritional content, therefore fortification with other ingredients is required to complement these nutrients, one of which is fortification with pineapple peel flour and chicken bones in noodle products. Thus, this study was conducted to investigate the impact of adding chicken bone and pineapple peel flours on the characteristics of wheat flour noodles, with the goal of developing a product enriched in fiber and minerals, and exhibiting acceptable sensory qualities. The research design used a completely randomized design (CRD) with 2 experimental factors, namely pineapple peel flour concentration (0%,3%,5%) and chicken bone flour concentration (0%,5%,10%) with triplicate replication. Based on the optimal treatment by Zeleny method, sample N1T3 emerged as the most favorable formulation. This sample exhibited the following chemical profile: a moisture content of 8.77%, an ash content of 4.52%, a protein content of 14.45%, a fat content of 1.52%, and a fiber content of 0.4%. Furthermore, sensory evaluation of Sample C yielded scores of 3.11 for color, 3.11 for aroma, 3.00 for taste, 2.89 for texture, and 2.89 for overall acceptance.

Kata kunci: Tulang Ayam, Mie, Kulit Nanas

Abstrak

Gandum memiliki kandungan gizi yang terbatas, oleh karena itu diperlukan fortifikasi dengan bahan lain untuk melengkapi kandungan gizi tersebut, salah satunya adalah fortifikasi dengan tepung kulit nanas dan tepung tulang ayam pada produk mie. Penelitian ini dilakukan untuk mengevaluasi pengaruh penambahan tepung tulang ayam dan kulit nanas sehingga menghasilkan mie yang tinggi serat dan mineral serta memiliki karakteristik sensori yang baik. Rancangan penelitian menggunakan Rancangan Acak Lengkap (RAL) dengan 2 faktor percobaan yaitu konsentrasi tepung kulit nanas (0%, 3%, 5%) dan konsentrasi tepung tulang ayam (0%, 5%, 10%) dengan 3 kali ulangan. Berdasarkan perlakuan optimal yang ditentukan melalui metode Zeleny, sampel N1T3 merupakan formulasi yang paling baik. Sampel ini menunjukkan karakteristik kimia (kadar air sebesar 8,77%, kadar abu sebesar 4,52%, kadar protein sebesar 14,45%, kadar lemak sebesar 1,52%, dan kadar serat sebesar 0,4%). Lebih lanjut, evaluasi sensorik terhadap Sampel N1T3 menghasilkan skor sebesar 3,11 untuk warna, 3,11 untuk aroma, 3,00 untuk rasa, 2,89 untuk tekstur, dan 2,89 untuk penerimaan keseluruhan.

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INTRODUCTION

Nowadays, noodles have become a staple food in Indonesia, ranking second in global consumption (Kingwell et al., 2018). While wheat flour, the primary ingredient, provides carbohydrates, it is deficient in essential amino acids, fiber, and minerals (Ma et al., 2022). To address this nutritional gap and reduce waste, this study proposes the fortification and substitution of noodles using pineapple peels and chicken bones. Blitar, a region known for its agricultural and livestock industries in East Java, offers a unique opportunity to source these materials locally. By utilizing these underutilized resources, we can enhance the nutritional profile of noodles while promoting sustainable practices and economic growth (Nurlaili & Aulia, 2019).

Pineapple is one of the most widely consumed fruit products globally. It is primarily consumed fresh or processed into canned fruit, juice, or jam. However, the pineapple processing industry generates significant waste in the form of peels, which constitute 34.7% of the total fruit weight (Wu & Shiau, 2015). Currently, the utilization of pineapple peels is limited, often relegated to animal feed. Yet, pineapple peels are rich in various phytochemical compounds, including dietary fiber and polyphenols (Sah et al., 2016). Furthermore, pineapple peel flour possesses substantial nutritional value, containing 3.8257% ash, 27.0911% crude fiber, 8.7809% crude protein, 1.1544% crude fat, and 13.65% reduced sugar (Ibrahim et al., 2018). Consequently, pineapple peels have the potential to serve as a valuable source of functional food ingredients such as high fiber. Fiber promotes health benefits such as prevent constipation, weight loss, reduce insulin sensitivity, and others (Barber et al., 2020). Previous studies indicate the utilization of pineapple pomace and stem as an additive in noodle production (Devi et al., 2023; Pinyo et al., 2024). However, the utilization of pineapple skin in noodles has not been investigated.

Chicken bones are solid waste often discarded as garbage or food waste, with limited utilization to date (Musdalifah et al., 2016). Given the significant consumption of chicken meat in the food industry, the utilization of chicken bones can positively impact waste management. Chicken bones are rich in minerals and protein (Kakimov et al., 2021; Prandi et al., 2024). Previous studies have successfully utilized chicken bones in food products like cookies and pâté (Cornelia & Gozali, 2018a; Kabdylzhar et al., 2023; Purwasih et al., 2019). While investigations concerning the incorporation of bone meal into noodles have been extensively conducted using sources like cork fish bone and Skate (Raja *kenojei*) skin and bone flour (Hartati et al., 2021; Kim et al., 2008), research specifically examining the application of chicken bones it remains understudied. This research aims to investigate the impact of pineapple peel flour and chicken bone flour on the physicochemical properties and sensory acceptability of noodles.

METHODS

Tools

The equipment used in this study were glassware such as erlenmeyer flask (Herma), beaker glass (Herma), measuring cylinder (Herma), sieve, noodle maker (Hoas), stove (Modena), dryer (Maksindo), steamer, and scales (Libramas).

Materials

The materials used in this study were chicken bones, pineapple peel, wheat flour, water, salt, and eggs, all of which were purchased from a local market in Blitar. The chemicals used for analysis included distilled water (Makmur, Indonesia), hydrochloric acid (Merck, USA), sodium hydroxide (Merck, USA), sulfuric acid (Merck, USA), Kjeldahl tablets (Merck, USA), hexane (Merck, USA), and boric acid (Merck, USA) were procured from Malang.

Research Design

The method was modified from (Cornelia & Gozali, 2018b; Pinyo et al., 2024). A completely randomized design (CRD) was employed, involving two experimental factors: pineapple peel flour concentration (N) and chicken bone flour concentration (T). These factors were combined to form nine treatments, each replicated three times, resulting in 27 experimental units. Table 1 presents the experimental design.

Table 1. Formulation of chicken bone flour and pineapple peels in noodle

Ingredients	Combination Treatment of Chicken Bone Flour and Pineapple Peels (%)								
	N1T1	**N1T2**	**N1T3**	**N2T1**	**N2T2**	**N2T3**	**N3T1**	**N3T2**	**N3T3**
Wheat Flour	50	50	50	50	50	50	50	50	50
Water	40	30	30	30	30	30	30	30	25
Egg	8	8	8	8	8	8	8	8	8
Salt	2	2	2	2	2	2	2	2	2
Chicken Bone Flour	-	5	10	-	5	10	-	5	10
Pineapple Peel Flour	-	-	-	3	3	3	5	5	5

Note:
N1T1= pineapple peel flour concentration (0%) and chicken bone flour (0%)
N1T2= pineapple peel flour concentration (0%) and chicken bone flour (5%)
N1T3= pineapple peel flour concentration (0%) and chicken bone flour (10%)
N2T1= pineapple peel flour concentration (3%) and chicken bone flour (0%)
N2T2= pineapple peel flour concentration (3%) and chicken bone flour (5%)
N2T3= pineapple peel flour concentration (3%) and chicken bone flour (10%)
N3T1= pineapple peel flour concentration (5%) and chicken bone flour (0%)
N3T2= pineapple peel flour concentration (5%) and chicken bone flour (5%)
N3T3= pineapple peel flour concentration (5%) and chicken bone flour (10%)

Test Parameters

a. Preparation of Chicken Bone Flour

Chicken bones were heated for 1 hour at 121^{o}C 2 atm. Next, the chicken bones were heated in a 60^{o}C oven for 12 hours. Then the heated chicken bones (10g) were ground for 2 minutes in a high-speed grinder. The fine sample was sieved with a 60-mesh sieve until chicken bone flour was obtained (Kong et al., 2024a)

b. Preparation of Pineapple Peel Flour

Pineapple peels were cremated at 60^{o}C for 8 hours using a cabinet dryer. The crisped pineapple peels were then ground for 2 minutes in a high-speed grinder. Samples that have been smooth, sieved with a 60-mesh sieve to obtain pineapple peel flour (Jose et al., 2022).

c. Procedure of Making Noodle

Noodles were made using a modified method (Ersyah et al., 2022) Wheat flour was mixed with chicken bone flour and pineapple peel with different concentrations. Then, the dough was added with warm water (45°C), eggs, and salt and kneaded until smooth. The dough was allowed to rest at room temperature for 30 minutes. The dough was flattened using a grinding tool (Ossel ZZ-150, Indonesia) with the thickest size for the first grinding, then resized to 3 mm which was repeated twice. The dough was then made into strands of noodles. The noodles were folded in half and steamed for 10 minutes at 100ºC. After steaming, the noodles were dried in the oven for 1 hour at 70°C, then fried for 75 seconds at 115°C. The noodles were put into polyethylene plastic and tested.

d. Proximate analysis

Proximate analysis consists of analysis of water content (SNI-2891-1192 item 5.1), ash content (AOAC 2016), crude protein (AOAC 2019), crude fat (SNI-2891-1992 item 8.1), and crude fiber (SNI-2891-1992 item 11).

e. **Sensory Analysis**

A total of 25 semi-trained panelists were asked to assess the appearance, aroma, taste, and texture of the noodle products. Each panelist was instructed to taste, then evaluate using a 1-5 Linkert scale. Number 1: very dislike, 2: dislike, 3: neutral; 4: like, 5: very like (Anggraeni et al., 2017).

Data Analysis

The collected data were analyzed using ANOVA using Minitab 17 with 95% confidence interval. If the test results showed a significant difference in the interaction between treatments, then proceed with the Bonferroni test. If there were no significant interactions between treatments, but one or both treatments had differences, then Fisher's test (BNT) 5% was conducted. To determine the optimal treatment, the Zeleny method was employed (Zeleny, 1998), integrating both the average proximate composition (moisture, ash, fiber, protein, fat, and carbohydrate content) and sensory attributes of the final product.

RESULTS AND DISCUSSIONS

Moisture Content

Based on the analysis presented in Table 2, the moisture content of the noodle products ranged from 7.93% to 13.23%. The results of the ANOVA test indicated a significant difference ($p < 0.05$) in moisture content as affected by the addition of pineapple peel and chicken bone flours. The significant variation in moisture content observed in the fortified noodle products can be attributed to the contrasting water-binding mechanisms of the two fortificants: pineapple peel flour contributes to increased moisture retention through its dietary fiber content (12-14%) and polysaccharides (cellulose, hemicellulose, and pectin) that possess strong water-binding capacity and can increase water absorption (Mehraj et al., 2024; Pasha et al., 2022), while chicken bone flour, with its high mineral content (30-31.4% calcium and optimal Ca:P ratio of 2:1), exhibits hygroscopic properties that compete with starch and protein for available moisture, thereby creating a complex interplay between fiber-mediated water binding and mineral hygroscopicity that ultimately determines the final moisture equilibrium in the noodle matrix (David et al., 2023; Sittikulwitit et al., 2004).

The incorporation of 3% pineapple peel flour increased the moisture content of the dried noodles compared to the control. This is likely attributed to the inherent moisture content of pineapple peel flour. Conversely, the addition of chicken bone flour to the noodle formulation resulted in a decrease in moisture content, aligning with previous research by (Uthai, 2021).

According to SNI 3551:2018 on dry noodles, the maximal moisture content is 10%. When compared with the Indonesian National Standard (SNI) levels, all samples have moisture content in accordance with SNI, except for N1T1, N1T3, and N3T3 which exceeds 10%. Moisture content significantly influences the shelf life of food products, as it impacts the growth of bacteria, molds, and yeasts (Purwasih et al., 2019).

Ash Content

Based on the analysis presented in Table 2, the ash content of the noodle products ranged from 1.49% to 4.69%. The results of the ANOVA test indicated a significant difference ($p < 0.05$) in ash content as due to the addition of pineapple peel and chicken bone flours. The observed data reveals a clear pattern: treatments with higher concentrations of chicken bone flour consistently exhibited elevated ash content levels. Specifically, samples containing 10% chicken bone flour (N1T3, N2T3, N3T3) achieved the highest ash values (4.52%, 4.21%, and 4.69% respectively), while control samples without chicken bone flour (N1T1, N2T1, N3T1) maintained lower ash levels (1.49%, 1.53%, and 1.16% respectively). This systematic increase demonstrates a direct dose-response relationship between chicken bone flour concentration and mineral content enhancement.

The phenomenon can be attributed to the fundamental compositional differences between the fortificants and wheat flour. Chicken bone flour inherently contains a substantially higher mineral density compared to wheat flour, as bones serve as the primary mineral reservoir in animal skeletal systems, particularly for calcium and phosphorus storage. When chicken bone flour replaces a portion of wheat flour in the formulation, it effectively concentrates the overall mineral content of the noodle matrix, resulting in proportionally higher ash values.

Pineapple peel flour also contributed to ash content elevation, though to a lesser extent than chicken bone flour. The treatments containing pineapple peel flour showed modest increases in ash content compared to wheat flour alone, indicating that this agricultural by-product possesses meaningful mineral content that enhances the nutritional profile of the noodles.

This finding is consistent with the fact that chicken bones are rich in minerals, containing approximately 0.55–0.63 g/g of mineral matter (Kong et al., 2024). Pineapple peel also contributes to the mineral composition, containing several minerals including calcium (3.31 mg/L), phosphate (223.8 mg/L), magnesium (62.50 mg/L), manganese (13.97 mg/L), iron (5.43 mg/L), and other trace elements (Budisantoso et al., 2020). These minerals play crucial roles in human metabolism, with requirements varying based on age, health status, and physical needs (Quintaes & Diez-Garcia, 2015).

Protein Content

The protein content of the noodle products enriched with pineapple peel and chicken bone flours, ranged from 11.91 ± 0.14% to 16.53 ± 1.34%. The ANOVA results showed a significant difference ($p < 0.05$) in protein content as influenced by the addition of these flours. The combination of 10% chicken bone flour and 5% pineapple peel produced the highest protein content (16.53 ± 1.34%) compared to other treatments.

Chicken bones have a chemical composition of 2.9% nitrogen, equivalent to approximately 15.6% protein, 9.5% fat, 14.7% minerals, and 57.5% water content. Collagen is the most abundant protein found in bones, skin, tendons, and other animal by-products (Musdalifah et al., 2016). Collagen, a high-molecular-weight protein, is insoluble in water due to its hydrophobic nature. To render collagen soluble, it must undergo a processing step to convert it into gelatin. This involves heating collagen in water at a temperature exceeding 40°C, the collagen shrinkage temperature (Cansu & Boran, 2015). Thus, the incorporation of chicken bone flour directly elevates the crude protein content while simultaneously improving the functional quality of the protein.

Pineapple peel flour, although lower in protein compared to chicken bone flour, also contributes to the overall protein content. Pineapple peel contains approximately 8% crude protein (Sari et al., 2025), derived from structural proteins, enzymes such as bromelain, and amino acid residues bound within its fibrous matrix. Bromelain, a proteolytic enzyme, not only adds to the protein value but may also aid in the hydrolysis of protein during processing, potentially enhancing digestibility in the noodle product.

According to the Indonesian National Standard (SNI) 3551: 2018 for dry noodles, the minimum protein content for noodle is 6%. Based on the test results, all samples met the requirements for quality, exceeding the minimum protein content.

Fat Content

The fat content of the noodle products formulated with pineapple peel and chicken bone flours, ranged from 0.93 ± 0.34% to 1.87 ± 0.65%. The ANOVA results showed no significant difference ($p > 0.05$) in fat content among the treatments. The highest fat content was observed in the N2T3 formulation, which contained 3% pineapple peel flour and 10% chicken bone flour. The contribution of chicken bone flour to fat content has been previously reported, as chicken bones contain approximately 9.5% fat (Musdalifah et al., 2016). This finding is consistent with (Purwasih et al., 2019), who noted that the incorporation of chicken bone flour can increase the fat content of food products. Furthermore, pineapple peel also contributes to the fat composition, as it contains about 2.53% fat, thereby influencing the overall lipid profile of the noodles (Mala et al., 2024).

Crude Fiber Content

The crude fiber content of the noodle products enriched with pineapple peel and chicken bone flours, ranged from 0.32± 0,23% to 1,17±0.37%. Although the ANOVA results indicated no significant difference ($p > 0.05$), a clear trend was observed in relation to the interaction of the two fortificants. Table 2 shows that increasing concentrations of pineapple peel flour were consistently associated with higher fiber levels in the noodles. This finding is consistent with the fact that pineapple peel contains approximately 12.05% fiber (Mala et al., 2024). In contrast, chicken bone flour does not contribute meaningful amounts of dietary fiber, as it is primarily composed of minerals (calcium, phosphorus), protein (collagen), and fat. As such, treatments with higher proportions of chicken bone flour tended to dilute the fiber contribution of pineapple peel flour in the dough matrix. This explains why the highest fiber content was observed in treatments with greater levels of pineapple peel flour, particularly when the substitution of wheat flour with chicken bone flour was minimized.

The interaction between these two materials therefore results in a balancing effect: while pineapple peel flour increases fiber levels due to its natural composition, chicken bone flour acts as a non-fiber component that can reduce the overall crude fiber concentration when used in higher amounts. This interplay highlights the importance of optimizing the ratio between the two fortificants to maximize nutritional value without compromising sensory and textural qualities of the noodles.

From a functional perspective, the enrichment of noodles with pineapple peel flour is particularly valuable. Insoluble fiber not only improves satiety and reduces caloric density but also enhances the structural integrity of noodles by binding water and modifying dough viscosity (Jovanovski et al., 2020; Suresh et al., 2020). Furthermore, fiber consumption has been linked to a reduced risk of various diseases, including cardiovascular disease, diverticulitis, constipation, irritable bowel syndrome, colon cancer, and diabetes (Fu et al., 2022). Thus, even though the differences in crude fiber across treatments were not statistically significant, the upward trend associated with pineapple peel incorporation demonstrates the potential of this by-product to improve the functional and health-promoting qualities of noodles.

Table 2. The results of proximate analysis on noodles

Proximate Analysis	**Combination Treatment of Chicken Bone Flour and Pineapple Peels (%)**								
	N1T1	**N1T2**	**N1T3**	**N2T1**	**N2T2**	**N2T3**	**N3T1**	**N3T2**	**N3T3**
Water Content (%)	11,08 ±0,39[c]	9,58 ±0,13[d]	8,77 ±0,09[e]	13,23 ±0,15[a]	8,86 ±0,07[e]	7,93 ±0,12[f]	8,96 ±0,12[de]	8,82 ±0,07[e]	11,91± 0,23[b]
Ash Content (%)	1,49 ±0,28[c]	3,24 ±0,10[b]	4,52 ±0,29[a]	1,53 ± 0,29[c]	3,11 ±0,12[b]	4,21 ±0,44[a]	1,16 ±0,23[c]	1,98 ±0,25[c]	4,69 ± 0,26[a]
Protein Content (%)	11,91 ±0,14[d]	13,36 ±0,36[cd]	14,45 ±0,34[bc]	15,22 ±0,84[abc]	14,65 ±0,12[abc]	14,86 ±0,59[abc]	15,60 ±0,40[ab]	15,77 ±0,61[ab]	16,53 ±1,34[a]
Fat Content (%)	1,49 ±0,36[a]	1,30 ±0,40[a]	1,52 ±0,39[a]	1,24 ±0,14[a]	0,93 ±0,34[a]	1,87 ±0,65[a]	0,94 ±0,25[a]	0,92 ±0,45[a]	1,60 ±0,29[a]
Carbohydrate content by difference (%)	73,71 ±0,13[a]	72,06 ±0,99[ab]	70,34 ±0,37[bc]	68,18 ±1,22[c]	71,88 ±0,50[ab]	70,37 ±0,29[b]	73,47 ±0,20[a]	71,34 ±0,34[ab]	64,41 ±1,15[d]

Crude Fiber content (%)	0,32 ±0,23[a]	0,47 ±0,33[a]	0,40 ±0,20[a]	0,60 ±0,39[a]	0,56 ±0,63[a]	0,76 ±0,59[a]	0,81 ±0,51[a]	1,17 ±0,37[a]	0,86 ±0,40[a]

Note: - Scores followed by unequal letters indicate significantly different (α=0.05)

Organoleptic Content

Organoleptic evaluation uses the hedonic method. Hedonic method is a sensory analysis designed to investigate the degree of quality difference between several similar products by evaluating the specific characteristics of the product (Tarwendah, 2017). The results of the hedonic test conducted by panelists can be shown in Figure 1.

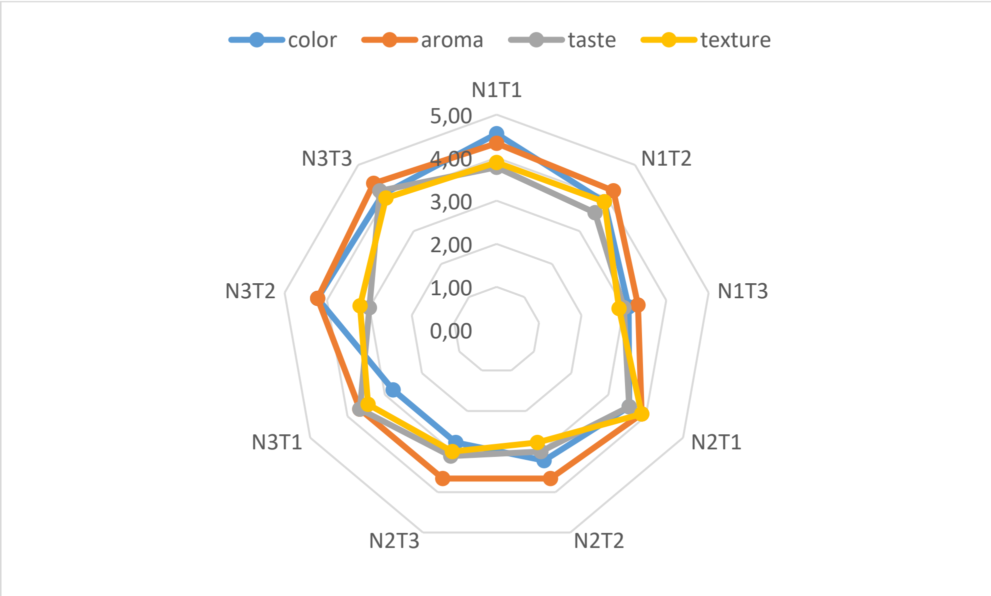

Figure 1. Hedonic test result

A. Color

Color is a crucial factor in attracting consumers, influencing their perception of product quality, and satisfying aesthetic preferences (Koh et al., 2022). Sensory evaluation of noodle products enriched with chicken bone and pineapple peel flours was conducted to assess color acceptability. Specifically, the color scores ranged from 2.78 to 4.56 across all treatments. The ANOVA results revealed a significant difference ($p < 0.05$) in color as influenced by the addition of these flours. Panelists generally preferred the color of the control noodles (N1T1) without chicken bone or pineapple peel flour, as they aligned with the familiar yellowish-white color of traditional noodles. In particular, the addition of pineapple peel resulted in a more pronounced yellowish hue in the noodle products. This color change can be attributed to the presence of carotenoid and xanthophyll pigments in pineapple peel, which contribute to the fruit's natural coloration (Hamidin et al., 2022). Meanwhile, chicken bone flour exhibited a color spectrum ranging from reddish to yellowish, a variation that arises from thermal processing leading to the decomposition of organic components in bone (Kong et al., 2024). This suggests that while the enhanced yellow color may provide visual appeal and indicate the presence of natural antioxidants, excessively intense coloration could potentially reduce consumer acceptance if it deviates too far from expected noodle appearance, as consumers typically associate traditional pale yellow or white colors with high-quality wheat noodles.

B. Aroma

The sensory evaluation results for the aroma parameter of noodles enriched with chicken bone and pineapple peel flours ranged from 3.33 to 4.44, with ANOVA results showing no significant difference ($p > 0.05$) among treatments. Although pineapple peel and chicken bone flours possess distinct aromas that could potentially enhance the overall aroma and flavor profile of noodle products, the aroma characteristics were not distinctly different across treatments.

The noodle sample with the highest average aroma score (4.44) was the formulation containing 10% chicken bone flour and 5% pineapple peel flour, indicating a rating between "like" and "very like" on the 5-point hedonic scale. However, this suggests that panelists found it difficult to discern meaningful aroma differences between treatments. This could be attributed to the relatively low concentrations of chicken bone flour and pineapple peel used in the study, which may have limited their aromatic impact.

These findings suggest that higher concentrations of these fortificants might be required to achieve more pronounced aroma enhancement, or alternatively, additional processing techniques such as controlled fermentation or enzyme treatment could be employed to enhance aroma release and improve the sensory profile of the fortified noodles.

C. Taste

The sensory evaluation results for the flavor parameter of noodles enriched with chicken bone and pineapple peel flours ranged from 3.00 to 4.22, as depicted in Figure 1. The ANOVA results showed no statistically significant difference ($p > 0.05$) in taste as influenced by the addition of these flours. All samples remained within the acceptable range on the hedonic scale, with scores falling between "neutral" (3.0) and "like" (4.0+), indicating that the fortified noodles-maintained consumer acceptability despite the ingredient modifications.

The absence of distinct flavor variation among noodle samples with varying concentrations of additives suggests that the relatively low concentrations of chicken bone flour (5-10%) and pineapple peel (3-5%) were insufficient to produce perceptible flavor enhancement. This finding indicates that while the fortificants did not negatively impact taste acceptance, higher concentrations may be necessary to achieve meaningful flavor differentiation and capitalize on the unique taste profiles that these ingredients could potentially contribute to noodle products.

D. Texture

The sensory evaluation results for the texture parameter of noodles enriched with chicken bone and pineapple peel flours ranged from 2.78 to 4.00 with scores falling between "dislike" (2.78) and "like" (4.00), as illustrated in Figure 1. The ANOVA results showed no significant difference ($p > 0.05$) in texture as influenced by the addition of these flours. This lack of statistical difference suggests that the relatively low concentrations of bone flour and pineapple peel used in this study had minimal impact on the overall texture characteristics compared to the control noodles.

The Optimal Treatment

The selection of the optimal treatment in this study was conducted using the Zeleny method, a multiple attribute decision making (MADM) approach that simultaneously considers various criteria to determine the optimal alternative. The determination of the most favorable formulation was based on the evaluation of nutritional content—encompassing moisture, fiber, carbohydrate, fat, and mineral levels—as well as the panelists' preference for sensory attributes.

Based on the analysis employing this method, sample N1T3, formulated with 0% pineapple peel and 10% chicken bone flours, was identified as the optimal treatment. This formulation exhibited favorable chemical characteristics, including a moisture content of 8.77%, an ash content of 4.52%, a protein content of 14.45%, a fat content of 1.52%, and a fiber content of 0.4%. Furthermore, the sensory parameters for sample N1T3, formulated with 0% pineapple peel and 10% chicken bone flours demonstrated scores for color (3.11), aroma (3.11), taste (3.00), texture (2.89), and overall acceptance (2.89), thereby substantiating its selection as the most outstanding formulation within the scope of this research.

CONCLUSION

Sample N1T3 (0% pineapple peel flour and 10% chicken bone flour) is the optimal formulation for noodle fortification. The optimal formulation achieved a nutritionally improved profile while preserving sensory acceptability, indicating the feasibility of this fortification strategy for commercial application. However, future research should focus on quantitative mineral bioavailability assessment, particularly calcium absorption studies, comprehensive consumer acceptance testing with larger populations, and shelf-life stability evaluation of the fortified products to support commercial viability and nutritional claims.

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