

Fresh Noodle Development with an Apple-Origin Wild Starter

ABSTRACT

Fresh noodles prepared with high-protein wheat flour and an apple-origin wild starter were developed and evaluated across four formulations using pH observations and hedonic responses. P1 contained no wild starter (0%), whereas P2, P3, and P4 contained 10%, 20%, and 30% wild starter relative to the high-protein wheat flour weight, respectively. The four formulations were treated as distinct complete formulations because the fed starter contributed additional flour and water. All four formulations underwent 3 h of room-temperature fermentation followed by 9 h of cold retardation. pH readings before and after the fermentation–retardation schedule were recorded as exploratory process observations. Thirty panellists rated colour, aroma, taste, texture, and elasticity on a five-point hedonic scale during two production/evaluation batches. The differences in pH readings for P1–P4 were 0.02, 0.02, 0.13, and 0.49 units, respectively. Hedonic responses were summarised by attribute. P4 had the highest percentage of ratings with scores of 4–5 for aroma (66.7%), taste (63.3%), texture (79.3%), and elasticity (70.0%), whereas P3 had the highest percentage for colour (63.3%). The exploratory five-attribute composite index produced different rankings by batch: P4 ranked highest in Batch 1, whereas P2 ranked highest in Batch 2. Because production batch, evaluation day, and panel composition changed concurrently, the findings are presented as exploratory descriptive evidence of the observed formulation and batch patterns.

Keywords: *fermented noodles, hedonic responses, pH, spontaneous fermentation, wild starter*

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Volume	: 2
Number	: 2
Year	: 2026
Received	: August 04, 2026
Revised	: August 23, 2026
Accepted	: September 07, 2026
Published	: September 30, 2026

ISSN 3064-1330 (Online)
DOI : 10.33649/66fm0m58

INTRODUCTION

Fermentation is a widely used food-processing method that can alter the physical, chemical, and sensory characteristics of food materials. During fermentation, microbial activity may produce metabolites that affect product aroma, taste, texture, and acidity. Fermentation is also applied to cereal-based products to modify product characteristics relative to conventional processing

(De Vuyst et al., 2023; Siddiqui et al., 2023).

Noodles are flour-based products whose final characteristics depend on the raw materials, formulation, and processing conditions. Fermentation of noodle dough has been reported to alter dough properties and the quality of the resulting product. Lu et al. (2022) associated fermentation with changes in starch characteristics and noodle quality, while

Xiong et al. (2021) reported that flour characteristics and fermentation processes affected the quality of fermented noodles. Research on fresh wheat noodles has also shown that sourdough systems may affect final product characteristics, particularly textural properties and noodle quality (Du et al., 2023). These findings support the further examination of fermentation in noodle product development.

One approach to fermenting flour-based products is the use of a wild starter. Unlike commercial cultures containing specified microorganisms, wild starters develop through spontaneous fermentation and may contain complex microbial communities. Their microbial composition can be influenced by the raw material, environmental conditions, temperature, fermentation time, and starter-maintenance procedure (De Vuyst et al., 2023). In this study, gas formation, volume increase, acidic aroma, and pH change were used as operational indicators of fermentation activity.

A wild starter was initiated with Fuji apple and subsequently maintained with wheat flour and water through repeated feeding. Apples contain sugars and organic components that can serve as substrates during fermentation. Guiné et al. (2021) described the use of apples in several fermented products and their capacity to support microbial activity. Apple chemistry, including sugar content, organic acids, and acidity, also varies with cultivar and fruit condition (Lončarić et al., 2023). The term apple-origin wild starter therefore refers to the starter material and lineage initiated from Fuji apple and subsequently maintained through repeated feeding with wheat flour and water.

Changes during fermentation may be associated with organic-acid formation and lower pH. In various food-fermentation systems, lactic acid bacteria can produce metabolites that contribute to acidification and sensory characteristics (Anumudu et al., 2024; Zapašnik et al., 2022). In the present study, pH readings were used as process observations to describe changes in acidity across the fermentation–retardation schedule.

Panellist liking is also relevant to fermented noodle development. Adding fermented material may alter aroma, taste, colour, texture, and elasticity, thereby affecting panellist liking. Studies of fermented noodles have reported sensory differences associated with fermentation procedures and ingredient formulations (Ahmad et al., 2023; Xiong et al., 2021). Formulations containing different amounts of wild starter therefore warrant sensory evaluation to describe panellist liking.

Previous studies have examined wheat-noodle fermentation using sourdough or defined cultures, particularly in relation to physicochemical and sensory quality (Du et al., 2023; Lu et al., 2022; Xiong et al., 2021). The present study builds on this literature by focusing on fresh high-protein wheat noodles prepared with a spontaneous starter lineage initiated from an apple mother starter and by documenting product development, pH observations, and batch-specific hedonic responses across four formulations.

Four formulations were examined: P1 without wild starter (0%) and P2, P3, and P4 with wild starter at 10%, 20%, and 30% of flour weight, respectively. These were considered four distinct complete formulations because the fed starter contributed additional flour and

water. The findings were therefore interpreted as a descriptive comparison of the product characteristics across the four tested formulations.

The study aimed to document the preparation of fermented fresh noodles with an apple-origin wild starter, compare pH readings across formulations P1–P4, and describe panellist hedonic responses for colour, aroma, taste, texture, and elasticity.

METHOD

This exploratory applied culinary product-development study used a descriptive comparison of four formulations. P1 contained no starter, whereas P2, P3, and P4 contained starter at 10%, 20%, and 30% of the high-protein wheat flour weight, respectively. Because the fed starter contributed flour and water, P1–P4 were treated as distinct complete formulations for descriptive comparison. The study documented the production process, pH readings before and after the fermentation–retardation schedule, and hedonic responses for five attributes.

Setting and Study Period

The study was conducted from May to June 2026 at Politeknik Pariwisata Makassar. Wild-starter preparation, dough mixing, fermentation, forming, and noodle cooking took place in the Practical Kitchen Laboratory of the Culinary Art Program. Hedonic evaluations were conducted in the Lobby Kitchen and Office Kitchen at Politeknik Pariwisata Makassar.

Materials and Equipment

The study materials included ingredients for the apple mother starter, wild-starter feeding, and fermented noodle production.

Table 1

Apple Mother Starter Formula

No.	Ingredient	Quantity	Specification
1	Fuji apple	100 g	Fresh, optimally ripe, unpeeled
2	Mineral water	200 g	Room temperature, non-chlorinated

Note. Adapted from Katz (2012) and Suas (2009).

Table 2

Wild-Starter Feeding Formula

No.	Ingredient	Quantity	Specification
1	Starter retained from the preceding feeding	50 g	Showing visible fermentation activity
2	High-protein wheat flour	100 g	Approximately 12–14% protein, free from lumps
3	Mineral water	50 g	Room temperature, non-chlorinated

Note. Adapted from Katz (2012) and Suas (2009).

Equipment included a digital scale, glass jars, knives, a chopping board, spatulas, stainless-steel bowls, gastronorm pans, food-grade plastic wrap, a pH meter, thermometer, stopwatch, chiller, noodle machine, cooker, and stockpot. All food-contact equipment was cleaned before use to reduce contamination during the study. Food-safety practices were implemented and documented in a food-safety logbook covering personal protective equipment, hand hygiene, equipment cleaning and sanitation, work-area control, and compliance with the standard operating procedure at each production stage.

Reference Noodle Formula

The reference noodle formula was adapted from The Culinary Institute of America (2011) and used as the basis for developing the fermented noodle formulations.

Table 3*Reference Noodle Formula*

No.	Ingredient	Quantity	Unit
1	High-protein wheat flour	454	g
2	Egg	3	pieces
3	Mineral water	50	g
4	Salt	3	g
5	Oil	15	g

Note. Adapted from The Culinary Institute of America (2011).

The reference formula served as the starting point for development trials incorporating wild starter at 0%, 10%, 20%, and 30% of flour weight.

Table 4*Initial Formula Before Development Trials*

No.	Ingredient	P1 (0%)	P2 (10%)	P3 (20%)	P4 (30%)	Unit
1	High-protein wheat flour	454	454	454	454	g
2	Egg	3	3	3	3	pieces
3	Mineral water	50	50	50	50	g
4	Salt	3	3	3	3	g
5	Oil	15	15	15	15	g
6	Wild starter	0	45.4	90.8	136.2	g

The amount of wild starter was calculated as a percentage of the high-protein wheat flour weight:

Wild starter weight = (wild starter percentage / 100) × high-protein wheat flour weight

At a high-protein wheat flour weight of 454 g, the calculated wild-starter quantities were 0 g for P1, 45.4 g for P2, 90.8 g for P3, and 136.2 g for P4.

The quantities of directly added high-protein wheat flour and water in the base formula were held constant across formulations, while the quantity of added wild starter differed. Because the wild starter also contained flour and water from feeding, P1, P2, P3, and P4 were treated as four distinct formulations. Their observed characteristics were subsequently compared.

Preparation of the Apple-Origin Wild Starter

Wild-starter preparation involved two stages: preparation of an apple mother starter and maintenance through repeated feeding.

1. Preparation of the Apple Mother Starter

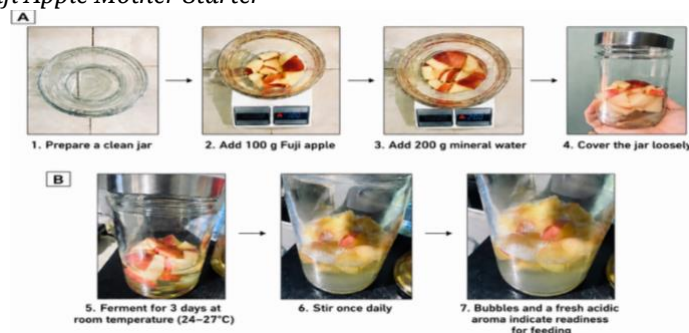
Fuji apple was selected as the initial material because juice from this cultivar has been reported at pH 3.69, while Fuji apple fruit contains simple sugars, including fructose, that may serve as microbial substrates during fermentation (Lee et al., 2017; Lončarić et al., 2023). These characteristics informed its selection for initiating the mother starter. The apple was used with both peel and flesh in the preparation of the mother starter. Guiné et al. (2021) reported that apple-based fermentations may include lactic acid bacteria and yeasts. The fruit flesh also contributes naturally occurring sugars, particularly fructose, that may serve as substrates during fermentation (Lončarić et al., 2023).

Apple Mother Starter Procedure

1. A 100 g portion of Fuji apple was cleaned and cut into small pieces without removing the peel.
2. The apple pieces were placed in a clean glass jar.
3. A 200 g portion of non-chlorinated mineral water was added to the jar.
4. The apple and water were stirred until evenly mixed.
5. The jar was covered loosely to allow gas produced during fermentation to escape.
6. The mixture was held at approximately 24–27 °C for 3 days.
7. The mixture was stirred once daily to reincorporate apple pieces floating at the surface.
8. The mother starter was observed daily for changes in appearance and aroma.
9. Feeding commenced when bubbles and a fresh acidic aroma became evident as operational signs of fermentation.
10. Once these signs were observed, the mother starter was used for the first feeding. The apple-origin wild starter was subsequently maintained through repeated feeding with wheat flour and water.

Figure 1

Stages in Preparing the Fuji Apple Mother Starter



2. Wild-Starter Feeding

After the mother starter showed visible fermentation activity, 50 g of the liquid phase of the fermented apple mixture was removed without apple pieces and used as the inoculum for the first feeding. The inoculum was mixed with 100 g of high-protein wheat flour and 50 g of mineral water. For each subsequent feeding, 50 g of flour-based starter from the preceding feeding was retained and mixed with the same quantities of flour and water. The composition of each feeding is presented in Table 5.

Table 5

Composition of Each Wild-Starter Feeding

Ingredient	Quantity
Starter retained from the preceding feeding	50 g
High-protein wheat flour	100 g
Mineral water	50 g
Total mixture	200 g

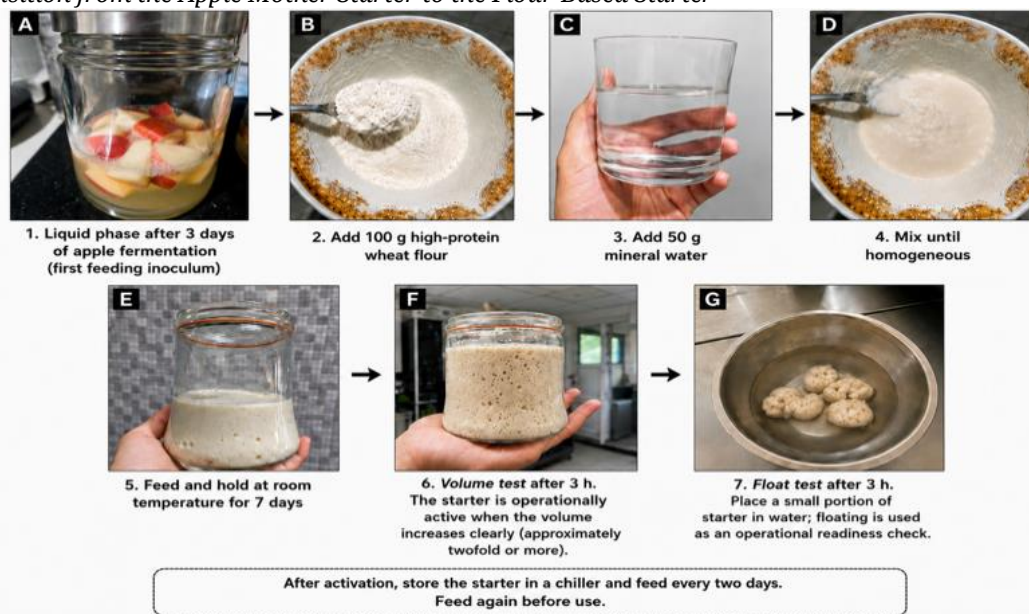
Wild-Starter Feeding and Maintenance Procedure

1. A 50 g portion of starter from the preceding stage was placed in a clean jar.
2. High-protein wheat flour (100 g) and mineral water (50 g) were added.
3. The mixture was stirred with a spatula until evenly combined and no dry flour remained.

4. The jar was covered loosely and held at approximately 24–27 °C.
5. The maturation phase lasted seven days at room temperature. Feeding was performed twice daily, at approximately 07:00 and 15:00, by retaining 50 g of the preceding starter and adding 100 g of high-protein wheat flour and 50 g of water to produce a 200 g mixture at each feeding.
6. During the seven-day maintenance period, the starter was observed for bubble formation, volume increase, aroma, and physical condition.
7. Operational readiness after feeding was assessed from bubble formation and an approximately twofold or greater volume increase within about 3 h; a float test was used as an additional culinary check. These criteria were used as operational screening before incorporating the starter into noodle production.
8. After meeting the operational-readiness criteria, the starter was transferred to cold maintenance. It was fed, held at room temperature for no more than 3 h, stored in a chiller, and subsequently fed every two days.
9. Before noodle production, the refrigerated starter was removed from the chiller and fed to restore visible fermentation activity.
10. After the pre-use feeding, the starter was held at room temperature until bubbles, increased volume, and a fresh acidic aroma were observed.
11. The volume and float tests were used as operational culinary screens before incorporating the starter into the dough.

Figure 2

Initial Transition from the Apple Mother Starter to the Flour-Based Starter



Note. Subsequent feedings used 50 g of starter retained from the preceding feeding.

Fermented Noodle Product Development

Before the main study, the fermented noodle product underwent three development trials to establish a workable formula and production procedure for the hedonic evaluation. Observations from each trial informed the procedural adjustment applied in the subsequent trial. Table 6 summarises the development process.

Table 6
Summary of the Three Fermented Noodle Development Trials

Development Trial	Formula/Modification	Observed Condition	Outcome and Decision
Trial I	Used the reference formula at one-third scale with 151 g high-protein wheat flour. Egg was standardised at 60 g, oil at 5 g, salt at 2 g, and water was adjusted from 16 g to 20 g	The initial dough was too dry. After forming, high-protein wheat flour used for dusting left the noodle strands sticky and difficult to separate	The 20 g water quantity was retained. Tapioca flour replaced high-protein wheat flour as the dusting flour in the next trial
Trial II	Used the Trial I formula with tapioca flour for dusting	Stickiness decreased, but a musty aroma and taste developed after chilled storage	Tapioca flour was retained but dry-toasted before use in the next trial
Trial III	Used the same formula with dry-toasted tapioca flour for dusting	The noodle strands remained separate, and the aroma was acceptable after chilled storage.	The formula and procedure were adopted for the main study.

The final base formula and production procedure were developed through three trials conducted at one-third scale, with adjustments made to the reference formula based on the observed production outcomes. At the development scale, 151 g of high-protein wheat flour was combined with 60 g of weighed egg; water was increased from the scaled quantity of approximately 16.7 g to 20 g to address excessive dough dryness; and salt was set at 2 g. The production formula was then scaled threefold to 453 g of high-protein wheat flour, 180 g of egg, 60 g of water, and 6 g of salt, while the oil quantity remained equivalent to that in the reference formula at 15 g. These adjustments resulted from the product-development trials.

Final Fermented Noodle Formulations

The three development trials established the final formulations used in the main study and hedonic evaluation.

Table 7
Final Fermented Noodle Formulations

No.	Ingredient	P1 (0%)	P2 (10%)	P3 (20%)	P4 (30%)	Unit
1	High-protein wheat flour	453	453	453	453	g
2	Egg	180	180	180	180	g
3	Mineral water	60	60	60	60	g
4	Oil	15	15	15	15	g
5	Salt	6	6	6	6	g
6	Wild starter	0	45.3	90.6	135.9	g
7	Dry-toasted tapioca flour	As required	As required	As required	As required	Processing aid; used as required

Wild starter was set at 10%, 20%, and 30% of the high-protein wheat flour weight. Dry-toasted tapioca flour was used as a processing aid during sheeting and cutting and was applied as required to reduce surface adhesion.

Fermented Noodle Production Process

After the final formulations had been established, all formulations followed the same production stages. P1, P2, P3, and P4 differed in the quantity of wild starter added.

A two-stage fermentation–retardation schedule was used: 3 h at a target room temperature of 25–30 °C followed by 9 h in a chiller at a target temperature of approximately 4 °C. The same schedule was applied consistently to all formulations, providing a common production condition for the descriptive comparison (De Vuyst et al., 2023; Grgić et al., 2024).

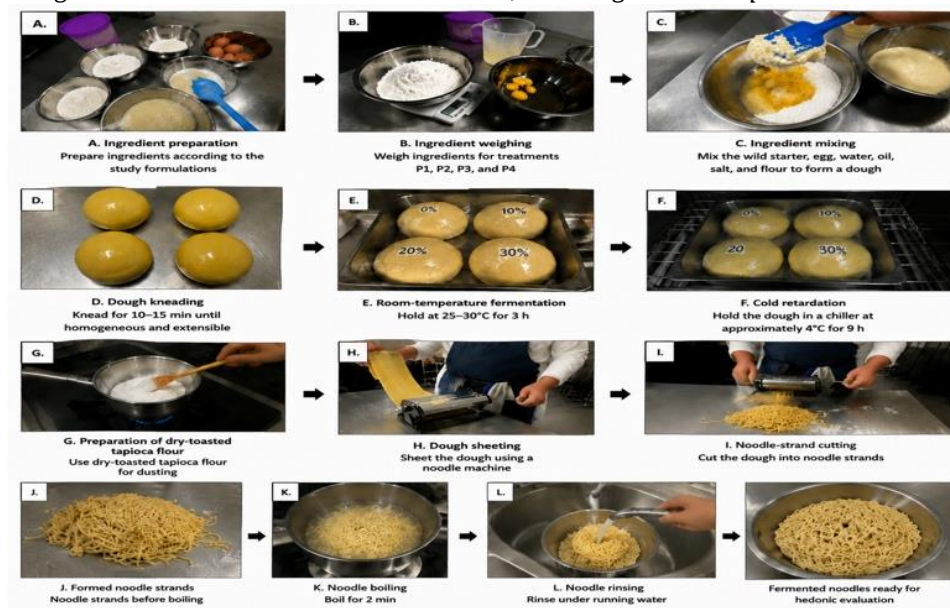
Fermented Noodle Production Procedure

1. All ingredients were weighed according to the relevant formulation.

2. High-protein wheat flour (453 g) was mixed evenly with 6 g of salt.
3. In a separate bowl, egg (180 g), mineral water (60 g), and oil (15 g) were combined until homogeneous.
4. Wild starter was added according to the final formulation: 0 g for P1, 45.3 g for P2, 90.6 g for P3, and 135.9 g for P4. Each production unit consisted of one batch of a single formulation at this scale.
5. The liquid ingredients were mixed until homogeneous; for P2–P4, the wild starter was evenly dispersed throughout the mixture.
6. A well was formed in the centre of the flour. The liquid mixture was added gradually while flour was drawn from the edges into the centre until the ingredients began to combine.
7. The dough was kneaded manually for approximately 10–15 min until cohesive, smoother in appearance, and sufficiently extensible for further processing.
8. The kneaded dough was shaped into a ball, and its surface was lightly oiled.
9. Each dough piece was wrapped in food-grade plastic wrap and labelled P1, P2, P3, or P4.
10. The dough was placed in a stainless-steel gastronorm pan and held at approximately 25–30 °C for 3 h during the room-temperature fermentation phase.
11. After the room-temperature phase, the dough was transferred to a chiller at a target temperature of approximately 4 °C for 9 h of cold retardation. The total fermentation–retardation schedule was 12 h.
12. Temperature and time can affect the fermentation of flour-based doughs (De Vuyst et al., 2023). The cold phase is described as retardation, a term used for low-temperature dough holding (Grgić et al., 2024), and was applied consistently across all formulations.
13. After cold retardation, the dough was removed from the chiller and held at room temperature for approximately 15 min.
14. The dough was divided into smaller portions for processing with the noodle machine.
15. Each portion was sheeted progressively to obtain dough sheets of uniform thickness.
16. During sheeting, dry-toasted tapioca flour was applied as required to reduce surface adhesion.
17. The dough sheets were passed through the noodle cutter to produce uniformly sized strands.
18. The formed noodle strands were placed in a clean container and lightly dusted with dry-toasted tapioca flour to prevent adhesion.
19. The noodles from each formulation were boiled for 2 min using the same procedure.
20. After boiling, the noodles were rinsed with clean water, drained, and prepared for hedonic evaluation.
21. All formulations underwent the same processing stages, fermentation–retardation schedule, and cooking time.

Figure 3

Stages in Producing Noodles Fermented with a Wild Starter, From Ingredient Preparation to the Finished Product



Exploratory pH Observations

pH observations recorded the acidity of the starter and differences in dough readings before and after the fermentation–retardation schedule. The pH meter was calibrated using pH 4.00 and pH 7.00 buffer solutions. After calibration, the electrode was rinsed with distilled water and dried with a lint-free tissue before use. The readings were treated as exploratory process observations describing acidity across the production sequence.

The pH of the mineral water and starter was recorded before production. For each formulation, the electrode was inserted directly into the dough before and after the fermentation–retardation schedule and held in place until the reading stabilised. The recorded values were used to describe pH changes across the fermentation–retardation schedule. The difference between pH readings was calculated as: $\Delta\text{pH} = \text{pH}_{\text{before}} - \text{pH}_{\text{after}}$

Figure 4

pH Measurement of the Wild Starter and Fermented Noodle Dough Using a pH Meter



Hedonic Evaluation

The hedonic evaluation described panellist liking of fermented noodles prepared with high-protein wheat flour and different quantities of wild starter. Panellists rated colour, aroma, taste, texture, and elasticity.

Thirty panellists provided hedonic ratings for the sensory evaluation: five had culinary experience as chefs, noodle producers, or culinary-arts lecturers, and 25 were students or consumers who regularly consumed noodles. Culinary experience was recorded as a participant characteristic, and all panellists completed the same hedonic evaluation.

The production structure comprised one dedicated pH-observation run and two separate production runs for hedonic evaluation; each run included P1–P4. Batch 1 involved 16 panellists, including one with culinary experience, whereas Batch 2 involved 14 panellists, including four with culinary experience. Each panellist evaluated all four formulations from one batch on the same evaluation day. Accordingly, batch-specific hedonic responses were interpreted within each production/evaluation occasion and alongside the pooled descriptive summary.

Table 8

Production and Measurement Matrix

Run	P1–P4 produced	pH recorded	Hedonic evaluation	Panellists
Dedicated pH-observation run	Yes	Before and after	–	–
Sensory Batch 1	Yes	–	Yes	16
Sensory Batch 2	Yes	–	Yes	14

Before evaluation, panellists received instructions for completing the questionnaire. Each formulation was presented under a sample code, and formulation identity was not disclosed. Each panellist evaluated all four formulations from the same production batch during the same evaluation session.

The evaluated samples comprised four formulations defined by the quantity of wild starter: P1 contained no wild starter (0%), while P2, P3, and P4 contained 10%, 20%, and 30% wild starter, respectively. Noodles from all formulations were cooked using the same procedure. Samples were served without seasoning so that panellists could assess the fermented noodles directly.

Panellists rated five sensory attributes:

1. Colour, referring to liking of the noodles' visual appearance.
2. Aroma, referring to liking of the product aroma.
3. Taste, referring to liking of the cooked noodles' taste.
4. Texture, referring to liking of the noodles' texture during consumption.
5. Elasticity, referring to liking of perceived elasticity and springiness.

Liking was rated on the five-point hedonic scale shown in Table 9.

Table 9

Five-Point Hedonic Scale

Score	Liking Anchor
5	Like very much
4	Like
3	Neither like nor dislike
2	Dislike
1	Dislike very much

Panellist ratings were compiled and analysed descriptively by sensory attribute and formulation. The hedonic evaluation was conducted with institutional research permission from Politeknik Pariwisata Makassar.

Data Analysis

The data were analysed descriptively using quantitative summaries. These summaries were used to characterise observations for the tested formulations and participating panellists.

Dough pH readings were analysed descriptively to summarise the difference before and after the fermentation–retardation schedule. The difference was calculated as:

$$\Delta\text{pH} = \text{pH}_{\text{before}} - \text{pH}_{\text{after}}$$

Hedonic data comprised panellist ratings for colour, aroma, taste, texture, and elasticity. Ratings were compiled by formulation, and the mean for each attribute was calculated as:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

$\bar{x}$ = mean score;

$\sum x_i$ = sum of all panellist scores for the same attribute and formulation;

n = number of panellists providing a score.

The mean was used as a descriptive summary and interpreted alongside the median, interquartile range (IQR), and distribution of scores 4–5. Scores 4 and 5 were classified as positive liking responses because their anchors were ‘Like’ and ‘Like very much’, respectively. The ordinal ratings were interpreted descriptively at the attribute and formulation levels (Lawless & Heymann, 2010).

Each attribute was summarised using the mean, median [IQR], and frequency of scores 4–5. The analysis included sensory data from 30 panellists. Available-case analysis was used for missing ratings. An exploratory composite index was calculated using an attribute-first algorithm: the mean of each attribute was calculated from the available values within a batch or the pooled data, and the five unrounded attribute means were then averaged with equal weighting. Final values were rounded to two decimal places. The composite index was used as an exploratory attribute-level summary across the five hedonic dimensions and was interpreted alongside the individual attribute results.

RESULTS

pH Observations for the Fermented Noodles

The measurements recorded the wild-starter pH and dough pH before and after the fermentation–retardation schedule for each formulation. Before use, the pH meter was calibrated with pH 4.00 and 7.00 buffer solutions.

Differences in pH readings were used to describe the pattern observed across formulations. The comparison was interpreted at the level of the complete formulations because the added starter also contributed flour and water.

The pH readings for the initial materials are presented in Table 10.

Table 10

pH Readings for the Initial Materials

Sample	pH
Mineral water	6.44
Wild starter	4.23

The mineral water had a pH of 6.44 and was near neutral, whereas the wild starter had a pH of 4.23 and was acidic at the time of measurement before noodle production. The starter pH was used as a descriptive process observation representing its acidity at the point of use.

The noodle dough was subsequently measured before and after the 12 h fermentation–retardation schedule. Table 11 presents the pH readings for each formulation.

Table 11

Dough pH Readings Before and After the Fermentation–Retardation Schedule

Formulation	pH Before the Schedule	pH After the Schedule	Difference in pH Readings
P1 (0%)	5.44	5.42	0.02
P2 (10%)	5.36	5.34	0.02
P3 (20%)	5.55	5.42	0.13
P4 (30%)	5.44	4.95	0.49

The second pH reading differed from the first by 0.02 units for P1, 0.02 for P2, 0.13 for P3, and 0.49 for P4. The differences were interpreted descriptively across the four complete formulations, with P4 showing the largest numerical change in pH readings.

Hedonic Evaluation Results

Hedonic responses for the four formulations across the two evaluation batches are summarised in Table 12.

Table 12

Hedonic Responses by Attribute and Formulation

Attribute	Formulation	n	Mean	Median [IQR]	Scores 4–5, n (%)
Colour	P1	30	3.43	3 [3–4]	14 (46.7)
Colour	P2	30	3.70	4 [3–4]	18 (60.0)
Colour	P3	30	3.63	4 [3–4]	19 (63.3)
Colour	P4	28	3.64	4 [3–4]	17 (60.7)
Aroma	P1	30	2.93	3 [2–3.5]	8 (26.7)
Aroma	P2	30	3.30	3 [3–4]	11 (36.7)
Aroma	P3	30	3.40	3 [3–4]	14 (46.7)
Aroma	P4	30	3.77	4 [3–4]	20 (66.7)
Taste	P1	30	3.17	3 [3–4]	10 (33.3)
Taste	P2	30	3.60	4 [3–4]	15 (50.0)
Taste	P3	30	3.53	3 [3–4]	14 (46.7)
Taste	P4	30	3.77	4 [3–4.5]	19 (63.3)
Texture	P1	30	3.23	3 [2–4]	13 (43.3)
Texture	P2	30	3.40	4 [3–4]	15 (50.0)
Texture	P3	30	3.43	3 [3–4]	13 (43.3)
Texture	P4	29	4.00	4 [4–5]	23 (79.3)
Elasticity	P1	30	3.00	3 [2–4]	11 (36.7)
Elasticity	P2	30	3.17	3 [3–4]	12 (40.0)
Elasticity	P3	30	3.47	4 [3–4]	15 (50.0)
Elasticity	P4	30	3.80	4 [3–4]	21 (70.0)

Note. Means and percentages use available-case denominators. For P4, colour n = 28 and texture n = 29; all other cells have n = 30.

Table 13

Proportions of Scores 4–5 by Attribute, Formulation, and Batch

Attribute	Batch	P1, n/N (%)	P2, n/N (%)	P3, n/N (%)	P4, n/N (%)
Colour	1	7/16 (43.8)	9/16 (56.2)	10/16 (62.5)	10/15 (66.7)
Colour	2	7/14 (50.0)	9/14 (64.3)	9/14 (64.3)	7/13 (53.8)
Aroma	1	4/16 (25.0)	5/16 (31.2)	9/16 (56.2)	11/16 (68.8)
Aroma	2	4/14 (28.6)	6/14 (42.9)	5/14 (35.7)	9/14 (64.3)
Taste	1	3/16 (18.8)	8/16 (50.0)	8/16 (50.0)	9/16 (56.2)
Taste	2	7/14 (50.0)	7/14 (50.0)	6/14 (42.9)	10/14 (71.4)
Texture	1	5/16 (31.2)	5/16 (31.2)	7/16 (43.8)	13/16 (81.2)
Texture	2	8/14 (57.1)	10/14 (71.4)	6/14 (42.9)	10/13 (76.9)
Elasticity	1	4/16 (25.0)	3/16 (18.8)	6/16 (37.5)	12/16 (75.0)
Elasticity	2	7/14 (50.0)	9/14 (64.3)	9/14 (64.3)	9/14 (64.3)

Note. Percentages use the available-case denominator in each cell. Batch 1 involved 16 panellists and Batch 2 involved 14 panellists.

Table 14*Exploratory Composite Index by Batch*

Batch	n panellists	P1	P2	P3	P4
Batch 1	16	2.96	3.15	3.56	3.95
Batch 2	14	3.37	3.76	3.41	3.62
Pooled	30	3.15	3.43	3.49	3.80

Note. The index was calculated using an attribute-first algorithm from unrounded attribute means and available-case denominators. Batch 1 involved 16 panellists; Batch 2 involved 14 panellists.

DISCUSSION

The largest difference in pH readings was observed for P4, followed by P3, while P1 and P2 showed the same difference. These differences are interpreted as formulation-level process observations because increasing amounts of starter also contributed additional flour and water to P2–P4.

The direction of the observed pH differences is broadly consistent with acidification reported in sourdough and fermented-noodle systems (De Vuyst et al., 2023; Du et al., 2023; Lu et al., 2022). These studies provide contextual support for interpreting the observed pH pattern within the specific starter, formulation, fermentation procedure, and measurement conditions used in the present study.

Attribute-level results provided the primary basis for sensory interpretation, with the composite index used as an exploratory summary across the five hedonic attributes. In the pooled data, P4 had the highest proportion of scores 4–5 for aroma, taste, texture, and elasticity, whereas P3 had the highest proportion for colour. Batch-specific descriptive analysis showed that P4 had the highest proportion of scores 4–5 for aroma, taste, and texture in both batches. For elasticity, P4 was highest in Batch 1, whereas P2, P3, and P4 had equal proportions in Batch 2. The colour pattern changed from P4 in Batch 1 to equal values for P2 and P3 in Batch 2. Because the instrument measured liking, texture and elasticity ratings were interpreted as hedonic responses to the perceived textural characteristics of the noodles.

Previous studies have also reported sensory or quality changes in fermented noodles (Ahmad et al., 2023; Du et al., 2023; Lu et al., 2022; Xiong et al., 2021). These studies provide contextual support for interpreting the present sensory findings across different flour types, cultures, formulations, processing conditions, and evaluation approaches.

The composite index provided an exploratory summary across the five hedonic attributes. P4 had the highest value in Batch 1, whereas P2 had the highest value in Batch 2. The change in ranking highlights the importance of interpreting the composite index alongside attribute-level and batch-specific results. P4 showed a consistent pattern for aroma, taste, and texture across the two batches, while colour, elasticity, and the composite index showed greater between-batch variation. Accordingly, sensory interpretation was based on the combined attribute-level and batch-specific evidence.

The study focused on curled fermented fresh noodles after boiling, with observations covering the production process, pH, and hedonic responses. For application in commercial

kitchens, the documented process provides a basis for subsequent starter standardisation, food-safety verification, time and temperature control, and repeated production assessment.

pH was observed by direct electrode insertion into semi-solid dough and interpreted as a process observation across the tested formulations. Hedonic evaluation was conducted on two production/evaluation occasions with different panellist groups. The resulting sensory evidence was interpreted at the batch-specific and pooled descriptive levels, reflecting the responses of the tested panellists to the prepared products.

CONCLUSION

Four fermented fresh noodle formulations containing 0%, 10%, 20%, and 30% apple-origin wild starter were prepared using room-temperature fermentation followed by cold retardation. The differences in pH readings before and after the fermentation–retardation schedule were 0.02, 0.02, 0.13, and 0.49 units for P1–P4, respectively. The pH values were interpreted as exploratory process observations recorded by direct electrode insertion during the production sequence. Attribute-level hedonic results showed that P4 had the highest proportion of scores 4–5 for aroma, taste, texture, and elasticity, whereas P3 had the highest proportion for colour. The exploratory attribute-first composite index produced different batch rankings: P4 ranked highest in Batch 1 and P2 in Batch 2. The variation in batch rankings supports interpretation of the composite index alongside the attribute-level results. Within the tested formulations and production/evaluation conditions, the findings describe distinct formulation- and batch-specific patterns in pH observations and hedonic responses. Subsequent studies can extend this work through independently replicated production batches, standardised pH and cooking protocols, and randomised or counterbalanced serving orders.

REFERENCES

- Ahmad, S., Nema, P. K., Nasir, G., Asfaq, Kheto, A., Vashishth, R., & Kumar, Y. (2023). Formulation and optimization of multigrain fermented noodles: A healthy and palatable convenience food option. *Journal of Food Processing and Preservation*, 2023(1), Article 8813705. <https://doi.org/10.1155/2023/8813705>
- Anumudu, C. K., Miri, T., & Onyeaka, H. (2024). Multifunctional applications of lactic acid bacteria: Enhancing safety, quality, and nutritional value in foods and fermented beverages. *Foods*, 13(23), Article 3714. <https://doi.org/10.3390/foods13233714>
- The Culinary Institute of America. (2011). *The professional chef* (9th ed.). John Wiley & Sons.
- De Vuyst, L., Comasio, A., & Van Kerrebroeck, S. (2023). Sourdough production: Fermentation strategies, microbial ecology, and use of non-flour ingredients. *Critical Reviews in Food Science and Nutrition*, 63(15), 2447–2479. <https://doi.org/10.1080/10408398.2021.1976100>
- Du, Y., Dai, Z., Hong, T., Bi, Q., Fan, H., Xu, X., & Xu, D. (2023). Effect of sourdough on the quality of whole wheat fresh noodles fermented with exopolysaccharide lactic acid bacteria. *Food Research International*, 172, Article 113108. <https://doi.org/10.1016/j.foodres.2023.113108>

- Grgić, T., Drakula, S., Voučko, B., Čukelj Mustač, N., & Novotni, D. (2024). Sourdough fermentation of oat and barley flour with bran and its application in flatbread made with no-time and dough retardation methods. *Fermentation*, 10(3), Article 174. <https://doi.org/10.3390/fermentation10030174>
- Guiné, R. P. F., Barroca, M. J., Coldea, T. E., Bartkiene, E., & Anjos, O. (2021). Apple fermented products: An overview of technology, properties and health effects. *Processes*, 9(2), Article 223. <https://doi.org/10.3390/pr9020223>
- Katz, S. E. (2012). *The art of fermentation: An in-depth exploration of essential concepts and processes from around the world*. Chelsea Green Publishing.
- Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices* (2nd ed.). Springer. <https://doi.org/10.1007/978-1-4419-6488-5>
- Lee, J., Jeong, M.-C., & Ku, K.-H. (2017). Chemical, physical, and sensory properties of 1-MCP-treated Fuji apple (*Malus domestica* Borkh.) fruits after long-term cold storage. *Applied Biological Chemistry*, 60(4), 363–374. <https://doi.org/10.1007/s13765-017-0288-6>
- Lončarić, A., Flanjak, I., Kovač, T., Tomac, I., Skoko, A.-M. G., Babojelić, M. S., Fruk, G., Zrinušić, S. Z., Čiček, D., Babić, J., & Jozinović, A. (2023). Unveiling apple diversity: The quality of juice produced from old vs. commercial apple cultivars. *Plants*, 12(21), Article 3733. <https://doi.org/10.3390/plants12213733>
- Lu, X., Guo, X., & Zhu, K. (2022). Effect of fermentation on the quality of dried hollow noodles and the related starch properties. *Foods*, 11(22), Article 3685. <https://doi.org/10.3390/foods11223685>
- Siddiqui, S. A., Erol, Z., Rugji, J., Taşçı, F., Kahraman, H. A., Toppi, V., Musa, L., Di Giacinto, G., Bahmid, N. A., Mehdizadeh, M., & Castro-Muñoz, R. (2023). An overview of fermentation in the food industry - looking back from a new perspective. *Bioresources and Bioprocessing*, 10(1), Article 85. <https://doi.org/10.1186/s40643-023-00702-y>
- Suas, M. (2009). *Advanced bread and pastry: A professional approach*. Delmar Cengage Learning.
- Xiong, X., Liu, C., Song, M., & Zheng, X. (2021). Effect of characteristics of different wheat flours on the quality of fermented hollow noodles. *Food Science & Nutrition*, 9(9), 4927–4937. <https://doi.org/10.1002/fsn3.2442>
- Zapaśnik, A., Sokołowska, B., & Bryła, M. (2022). Role of lactic acid bacteria in food preservation and safety. *Foods*, 11(9), Article 1283. <https://doi.org/10.3390/foods11091283>