International Journal of Agricultural Technology 2026 Vol. 22(6):2719-2732
DOI: https://doi.org/10.63369/ijat.2026.22.6.2719-2732
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Production practices and product variability of traditional Nam Ô fish sauce in Vietnam

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Le, V. T., Nguyen, T. T. T., Vu, T. D., Le, C. B., Tran, T. T. T., Vo, T. K. H., Nguyen, D. T. H., To, T. T., Pham, T. T., Tran, H. O., Pham, K. T., Bui, T. P., Nguyen, V. D. and Pham, C. H. (2026). Production practices and product variability of traditional Nam Ô fish sauce in Vietnam. International Journal of Agricultural Technology 22(6):2719-2732.

Abstract This baseline study is described production practices and product variability of traditional Nam Ô fish sauce. Among 71 Nam Ô fish-sauce producers surveyed, 12 (16.9%) was measured fish and salt exclusively by mass, 30 (42.3%) was shown exclusively by volume and 29 (40.8%) was mixed or unclear conventions; 37 (52.1%) was recorded as the nominal 10:4 fish-to-salt formulation. Forty-two producers (59.2%) found to be monitoring no technical parameter during fermentation, nine (12.7%) was some monitoring, and 20 (28.2%) gave no interpretable response. Ingredient sourcing followed a broadly shared traditional framework, whereas operational practices varied or incompletely documented. In ten commercial products are coded as genuine (*nguyên chất*), total nitrogen (TN) ranged from 19.5 to 31.6 g/L and amino-acid nitrogen as a proportion of TN (AAN/TN) from 9.9% to 48.4%. Four, three and one product met the AAN/TN benchmarks of the Vietnamese standard TCVN 5107:2018 (≥35%), Codex CXS 302-2011 (≥40%) and the Nam Ô geographical indication (GI; >43.5%), respectively; nine met the GI TN benchmark (≥20 g/L). Absolute AAN was 7.2-10.4 g/L in nine products and 3.1 g/L in one product. Benchmarks were applied retrospectively to single determinations, which is required confirmation. Sensory scores for 30 products showed product differences together with strong panellist effects, limiting claims about consumer preference or GI typicity. The baseline is supported prospective evaluation of measured salt dosing, minimum batch records, documented pre-salting time-temperature history and traceable lot-level verification. Survey and product records could not be reliably paired, so effects of individual practices on product composition could not be estimated.

Keywords: Amino-acid nitrogen, Anchovy, Artisanal fermentation, Batch traceability, Salt dosing

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Introduction

Fish sauce is a high-salt fermented condiment produced by proteolysis of fish proteins during prolonged maturation with salt. Across Southeast Asia, its composition and sensory characteristics depend on fish species and freshness, salt quality and dose, fermentation temperature and duration, mixing or liquid recirculation, microbial ecology and post-fermentation handling (Lopetcharat *et al.*, 2001; Zaman *et al.*, 2009). These factors interact: salt level affects proteolysis and microbial selection, raw-material freshness affects flavour and biogenic-amine risk, and fermentation time shifts the balance between total soluble and amino-acid nitrogen. Traditional fish sauce is therefore not a single standardized matrix but a family of products shaped by local knowledge and process conditions.

This process dependence is particularly important for histamine. Biogenic amines can form when histidine-decarboxylating microorganisms are present in the raw fish or become established during fermentation. Temperature abuse before salting can increase histamine formation, and salting does not necessarily remove the risk because halophilic or halotolerant histamine-forming bacteria may persist under fish-sauce fermentation conditions (Kimura *et al.*, 2001; Yongsawatdigul *et al.*, 2004; Shim *et al.*, 2022). Recent studies of commercial Asian fish sauces and of Vietnamese traditional fish sauce accordingly treat histamine as a central food-safety variable (Huang *et al.*, 2025; Pham *et al.*, 2025). For traditional producers, risk management therefore begins at raw-fish reception and continues through salting and maturation; it cannot rely on final-product inspection alone. Because histamine could not be measured here (see Materials and methods), this risk is treated as the rationale for documenting pre-salting time-temperature history.

Quality regulation of fish sauce also relies on several compositional criteria. The Vietnamese standard TCVN 5107:2018 (Ministry of Science and Technology, 2018) and the Codex standard CXS 302-2011 (Codex Alimentarius Commission, 2011) both use total nitrogen (TN) and amino-acid nitrogen (AAN) as a proportion of TN (AAN/TN), but with different thresholds. Codex additionally specifies a minimum NaCl content (200 g/L) and a histamine limit (40 mg/100 g); TCVN 5107:2018 additionally specifies ammonia nitrogen (NH_3-N), pH and NaCl criteria and distinguishes genuine fish sauce (*nước mắm nguyên chất*) from products that may contain added ingredients. For a geographically protected product, the local specification adds a third layer of stricter compositional attributes and process features intended to preserve identity. The regulatory question is therefore not only whether a product passes a single

standard, but which characteristics vary most and which practices producers can realistically control.

Nam Ô is a long-established fish-sauce producing area in Da Nang, central Vietnam. The product is associated with anchovy and sea salt, household-scale fermentation, pressing, and subsequent mixing or maturation. Nam Ô fish sauce received geographical indication (GI) protection in June 2024 under Decision No. 437/QD-SHTT (GI registration No. 00138; Intellectual Property Office of Vietnam, 2024). The registered specification includes TN ≥20 g/L, AAN/TN >43.5%, NH_3-N/TN <14.2%, seasonal fish-to-salt ratios of 3:1 and 2.5:1, and a prolonged maturation sequence involving pressing and stirring. Because the producer survey was conducted in 2023 and product sampling extended across 2023-2024, the dataset is a baseline around, rather than entirely after, GI establishment. Comparisons with GI criteria are therefore retrospective benchmarking, not legal determinations of producer compliance.

Earlier Vietnamese work has described production conditions and product quality in other GI fish-sauce systems, including a survey of Phu Quoc producers and products (Nguyen *et al.*, 2019). The Nam Ô dataset is extended by combining producer-level operational practices with commercial product quality and simultaneous benchmarking against national, Codex and GI criteria, with a reproducible data-cleaning trail. It is allowed a systems-level assessment of whether heterogeneity resides in the ingredient base, in process execution or in product composition, and which minimum controls could reduce avoidable variability without erasing traditional diversity.

The questions are asked as how heterogeneous production practices are among Nam Ô producers and where heterogeneity concentrates, how variable commercial Nam Ô products are in nitrogen composition and sensory response, which nitrogen benchmarks are most restrictive when products are retrospectively compared with TCVN 5107:2018, Codex CXS 302-2011 and the subsequently established Nam Ô GI specification, and which process variables could serve as minimum measurable control points for GI management.

The hypothesis for research objectives was conveyed to the ingredient framework, as coded in the survey which would be comparatively consistent, whereas operational control - salt dosing, pressing and stirring, fermentation duration and monitoring that would be more heterogeneous.

Materials and methods

Study design and sampling

This cross-sectional baseline study, conducted in Da Nang, Vietnam, combined a 2023 producer survey, commercial-product measurements (2023-

2024) and sensory records. The survey frame contained 74 records; structured interviews covered sourcing, dosing, fermentation, monitoring, certification and release. A duplicate record, an unusable company record and a producer of a rapidly fermented product were excluded, leaving 71 producers; coverage beyond the frame was unknown. Free text was conservatively recoded, missing responses were retained as missing, and ratios were normalized only when unambiguous. Measurement basis was exclusive mass, exclusive volume or mixed/unclear; ingredient categories were coarser than process categories.

The 28 chemical products comprised 15 Nam Ô products (ten genuine, *nguyên chất*, MO; five regular grade, *loại thường*, MT), ten from other Vietnamese origins (MP) and three imported references (MN). Nam Ô samples were recorded as collected in 2024 and other-origin samples in 2023; dates and lot metadata were incomplete. Each product was one bottle or lot, without repeated-lot sampling. Six anchovy-plus-salt products without declared additives (MP4, MP6-MP10) formed the strict comparator set; other formulations were excluded. These comparators were not geographically representative. Survey and product records could not be reliably paired; chemical and sensory records were analysed separately.

Chemical measurements and benchmarks

TN, AAN and amino-plus-ammonia nitrogen were obtained from project records and QUATEST 2 reports (TCVN 3705:1990, 3708:1990 and 3707:1990, respectively). All 84 entries were checked against the reports and eight transcription discrepancies were corrected. Each product had one determination per parameter; replicate precision and uncertainty were unavailable. AAN/TN was calculated from concentrations. TCVN 3707 formol nitrogen was not treated as direct ammonia nitrogen (TCVN 3706), and nitrogen fractions were not subtracted to estimate NH_3-N. Histamine, NaCl, pH and microbiological endpoints were not analysed because analytical documentation, units or sample alignment across lots could not be verified.

Retrospective benchmarks were TN ≥10 g/L with AAN/TN ≥35% (TCVN 5107:2018) or ≥40% (Codex CXS 302-2011), and TN ≥20 g/L with AAN/TN >43.5% (Nam Ô GI). Counts did not establish full-standard or legal compliance. The survey and some samples predated the June 2024 GI registration.

Sensory evaluation

Twelve internal panellists scored 30 three-digit-coded products (110-139) on a 1-9 quality scale for colour, clarity, overall odour, fishy odour, saltiness,

umami, savoury/body, aftertaste, thickness and overall quality. This was an in-house preliminary quality evaluation, not trained descriptive analysis or a consumer test. Panellist-level scores were analysed without imputation. Missing or invalid scores numbered one for saltiness, two each for umami, savoury/body and aftertaste, and 15 for overall quality. Additive analysis of variance (ANOVA) on the available observations used type II sums of squares, without a product × panellist interaction (one score per cell; residual df 304-319). The average-score intraclass correlation coefficient, ICC(2,k), was calculated as $(F_{product} - 1)/[F_{product} + (F_{panellist} - 1)/30]$, where 30 is the number of products (Shrout and Fleiss, 1979).

Statistical analysis

Categorical variables were summarized as counts, percentages and Wilson 95% confidence intervals (CI); chemical measurements as medians, ranges and coefficients of variation (CV). Simpson diversity, $D = 1 - \Sigma p_i^2$, used interpretable dosing-basis (n = 44, including two mixed/ambiguous records) and stirring responses (n = 54), excluding 27 and 17 unclear or unreported records, respectively. Genuine products and strict comparators were compared by two-sided Mann-Whitney tests and Hodges-Lehmann location-shift estimates (median pairwise differences) with percentile bootstrap CI (20,000 resamples). Spearman correlations were calculated for pooled Nam Ô products, each Nam Ô class and strict comparators. Subgroup analyses were exploratory; absolute AAN was examined because TN is the denominator of AAN/TN. Calculations were performed in Python (pandas, SciPy) with linear models.

Results

Producer profile and operational practices

Sixty-six of 71 producers (93.0%) were household operations. Sa Huynh salt was the only source for 58 producers (81.7%), and 52 (73.2%) reported local fish supply. Eighteen reported a certification or food-safety eligibility credential, 33 explicitly reported none or not yet, and 20 gave missing or unclear information. Ingredient sources were comparatively concentrated, whereas dosing, stirring and monitoring practices varied (Table 1).

Exclusively mass-based dosing was reported by 12 producers (16.9%; 95% CI 9.9-27.3%) and exclusively volumetric dosing by 30 (42.3%; 31.5-53.8%); the remaining 29 comprised two mixed/ambiguous and 27 unclear responses. A nominal 10:4 fish-to-salt ratio was reported by 37/71 (52.1%; 40.7-63.3%). Some

producers adjusted salt for fish freshness, size, season or salt quality, so the number of alternative normalized ratios depended on coding.

Pressing followed by stirring was reported by 39 producers, but only 17 specified periodic stirring. Among 14 reporting the salting-to-pressing interval, the median was 10 days (range 1-30). Minimum fermentation time was 12 months for 51 producers, with reported upper bounds up to 18 months. Twenty-seven producers fermented outdoors or in mixed indoor/outdoor locations. Forty-two producers reported no technical monitoring (59.2%; 47.5-69.8%), nine some and 20 gave no interpretable response; among the 51 interpretable responses, 42 (82.4%; 69.7-90.4%) reported none. Release was most often judged by colour (62 producers); two cited a nitrogen criterion. Freshness was assessed by firmness, appearance, intactness and odour, and 11 producers avoided iced fish.

Simpson diversity was 0.46 for dosing basis (n = 44) and 0.72 for stirring schedule (n = 54). Retrospective concordance with GI process elements was 47/71 for a nominal fish-to-salt ratio (66.2%), 52/71 for 12-18 months of fermentation (73.2%), 17/71 for pressing followed by periodic stirring (23.9%) and 10/71 for all three (14.1%); these are upper-bound descriptive counts because seasonal and measurement-basis concordance could not be verified.

Table 1. Producer characteristics and production practices (n = 71)

Domain	Response category	n	%
Producer type	Household	66	93.0
	Cooperative	4	5.6
	Company	1	1.4
Salt source	Sa Huynh only	58	81.7
	Ca Na only	4	5.6
	Both	5	7.0
	Other/unknown	4	5.6
Fish source	Local	52	73.2
	Local + regional	19	26.8
Certification status	At least one certification / food-safety eligibility credential	18	25.4
	Explicitly none / not yet	33	46.5
	Missing or unclear	20	28.2
Fish:salt measurement	Exclusive mass basis	12	16.9
	Exclusive volume basis	30	42.3
	No single exclusive basis	29	40.8

Domain	Response category	n	%
Nominal formulation	10 fish : 4 salt	37	52.1
Fermentation method	Pressing only	25	35.2
	Pressing + stirring	39	54.9
	Pressing + drawing	4	5.6
	Other (undisturbed, n = 2; stirring-based, n = 1)	3	4.2
Stirring schedule	Periodic with stated schedule	17	23.9
	Only before filtration	12	16.9
	Stirring, schedule unspecified	19	26.8
	No stirring stated	6	8.5
	Not reported	17	23.9
Minimum fermentation time	<12 months	19	26.8
	12 months	51	71.8
	>12 months	1	1.4
Process monitoring	Explicitly none	42	59.2
	Some monitoring	9	12.7
	No interpretable response	20	28.2
Release criterion	Nitrogen criterion reported	2	2.8
	Colour criterion reported	62	87.3
Fermentation location	Roofed indoor	43	60.6
	Outdoor	14	19.7
	Mixed/sequential indoor-outdoor	13	18.3
	Unroofed indoor	1	1.4

Percentages use 71 producers and may not sum to 100% owing to rounding. The 29 non-exclusive dosing responses comprised two mixed/ambiguous and 27 unclear records. Missing monitoring and certification responses are shown separately; release criteria were not mutually exclusive.

Nitrogen composition and retrospective benchmarks

Genuine Nam Ô products had TN of 19.5-31.6 g/L (median 29.3 g/L; CV 18.1%) and AAN/TN of 9.9-48.4% (median 30.6%; CV 34.1%). Absolute AAN was 7.2-10.4 g/L in nine products and 3.1 g/L in MO2 (median of all ten, 8.5 g/L). Group summaries and genuine-product data are given in Tables 2 and 3. The five regular-grade products (a local grade label analysed separately from genuine products) had TN of 4.8-23.4 g/L, two of them below 10 g/L, and AAN/TN of 5.8-24.6%; none reached 35%.

Table 2. Nitrogen composition of commercial product groups

Group	n	TN range (g/L)	TN median (g/L)	AAN/TN range (%)	AAN/TN median (%)	AAN range (g/L)	AAN median (g/L)
Nam Ô genuine (*nguyên chất*)	10	19.5-31.6	29.3	9.9-48.4	30.6	3.1-10.4	8.5
Nam Ô regular grade (*loại thường*)	5	4.8-23.4	17.9	5.8-24.6	20.9	0.3-5.0	3.9
Strict comparator: anchovy + salt	6	18.4-41.3	23.9	25.8-37.3	33.7	5.0-15.4	8.0

TN, total nitrogen; AAN, amino-acid nitrogen; AAN/TN, AAN as a percentage of TN. Ranges are minima-maxima of single determinations; n denotes products.

Table 3. Nitrogen data and benchmark outcomes for ten genuine Nam Ô products

Code	TN (g/L)	AAN (g/L)	AAN/TN (%)	Amino-plus-ammonia N (g/L)	TN ≥20 g/L (GI)	AAN/TN benchmarks met
MO1	23.0	9.73	42.3	15.4	Yes	TCVN, Codex
MO2	31.2	3.08	9.9	13.3	Yes	None
MO3	29.5	8.54	28.9	14.5	Yes	None
MO4	21.5	10.4	48.4	15.7	Yes	TCVN, Codex, GI
MO5	20.7	8.54	41.3	12.3	Yes	TCVN, Codex
MO6	31.6	7.63	24.1	15.2	Yes	None
MO8	19.5	7.21	37.0	12.2	No	TCVN
MO9	29.1	8.82	30.3	17.0	Yes	None
MO10	29.7	8.12	27.3	16.7	Yes	None
MO11	30.2	9.31	30.8	17.2	Yes	None

TN and AAN are in g/L; AAN/TN is a percentage. Amino-plus-ammonia nitrogen is the TCVN 3707 result, not direct ammonia nitrogen. Outcomes refer to retrospective nitrogen benchmarks, not full-standard compliance.

All ten genuine products met the TCVN/Codex TN minimum, and nine met the GI TN criterion. Products meeting the AAN/TN threshold fell from four (TCVN) to three (Codex) and one (GI) (95% CI 16.8-68.7%, 10.8-60.3% and 1.8-40.4%, respectively (Table 4, Figure 1). AAN was not significantly correlated with TN (Spearman $\rho = -0.30$, $p = 0.40$ for all ten products; $\rho = -0.07$, $p = 0.86$ without MO2).

Table 4. Retrospective nitrogen benchmarks for ten genuine Nam Ô products

Criterion	Reference threshold	Products (n/N)
TN	TCVN/Codex ≥10 g/L	10/10
TN	Nam Ô GI ≥20 g/L	9/10
AAN/TN	TCVN ≥35%	4/10
AAN/TN	Codex ≥40%	3/10
AAN/TN	Nam Ô GI >43.5%	1/10

GI, geographical indication. Benchmarks were applied to single determinations, and the GI specification postdated part of the sampling. Counts do not establish legal compliance.

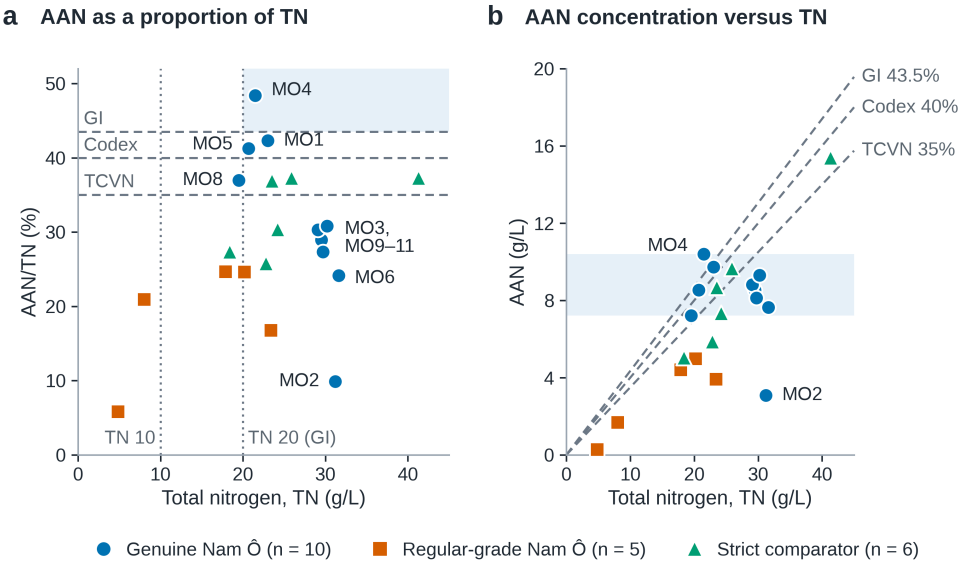


Figure 1. TN versus (a) AAN/TN and (b) absolute AAN in genuine (n = 10) and regular-grade (n = 5) Nam Ô products and strict comparators (n = 6); Dashed lines: TCVN, Codex and GI thresholds (35%, 40% and 43.5% AAN/TN in a; the AAN needed to meet them in b); dotted lines: TN thresholds (10 g/L, TCVN and Codex; 20 g/L, GI). Shading: region meeting both GI criteria (a); AAN range of nine genuine products, 7.2-10.4 g/L (b); MO2 had 3.1 g/L. Each point is one determination.

As compared with six strict comparators, genuine products showed no significant differences in TN (medians 29.3 versus 23.9 g/L; Mann-Whitney p = 0.64), AAN/TN (30.6% versus 33.7%; p > 0.99) or AAN (8.5 versus 8.0 g/L; p = 0.87). Hodges-Lehmann differences (genuine minus comparator) were 3.4 g/L for TN (95% bootstrap CI −8.1 to 6.9), 0.0 percentage points for AAN/TN (−8.1 to 8.1) and 0.2 g/L for AAN (−5.0 to 2.7).

The TN-AAN/TN correlation was near zero across the 15 Nam Ô products ($\rho = 0.04$, $p = 0.89$). Exploratory coefficients were −0.81 ($p = 0.005$) in genuine products, −0.75 ($p = 0.020$) after excluding MO2, and +0.30 ($p = 0.62$) in regular-grade products. The strict comparators, analysed separately and excluded from the pooled Nam Ô coefficient, had $\rho = +0.83$ ($p = 0.042$).

Sensory product and panellist effects

The product effects were significantly found for all ten attributes ($F = 3.50$-7.23; $p < 0.001$), and panellist effects were still larger one ($F = 17.11$-33.17; $p < 0.001$). Average-score ICC ranged from 0.55 for thickness to 0.80 for clarity (Table 5). These internal-panel results describe product variation and panellist differences.

Table 5. Sensory statistics for 30 products scored by 12 internal panellists

Attribute	F (product)	F (panellist)	ICC(2,k)
Colour	7.10	22.34	0.78
Clarity	7.23	18.65	0.80
Overall odour	6.44	20.43	0.77
Fishy odour	4.81	21.44	0.69
Saltiness	3.81	19.54	0.63
Umami	3.60	26.38	0.58
Savoury/body	4.01	28.44	0.61
Aftertaste	4.18	17.75	0.67
Thickness	3.50	33.17	0.55
Overall	5.23	17.11	0.73

All product and panellist main effects had $p < 0.001$. Missing scores were not imputed; ANOVA used available observations. ICC(2,k) is the average-score estimate.

Discussion

Operational control and traditional practice

The survey indicated a shared ingredient framework alongside varied operational control. Local fish supply, Sa Huynh salt and the common nominal 10:4 formulation coexist with mass, volumetric and unclear dosing, variable pressing and stirring schedules, and limited technical monitoring. Because ingredient and process categories were coded at different levels of detail, their

diversity indices cannot be ranked, and comparisons with Phu Quoc are constrained by differences in sampling and analytical design (Nguyen *et al.*, 2019). The practical targets therefore appear to be measurement and record-keeping gaps rather than a hierarchy of traditional practices.

A nominal ratio was insufficient for reproducible dosing when utensils substitute for weighing. Bulk density varies with salt crystal size, packing, moisture, fish size and drainage, so identical volume ratios need not give identical salt mass fractions. The survey showed that conventions differed but not their mass equivalents. Weighing the contents of representative utensils, then prospectively evaluation calibrated mass dosing that would address this gap without asking producers to abandon their vessels or sensory selection.

Nitrogen criteria and interpretation

AAN/TN was more variable and more restrictive than TN in the genuine-product set, consistent with the use of complementary nitrogen indicators (Lopetcharat *et al.*, 2001; Huang *et al.*, 2025). This partly reflects the form of the criterion: at the GI threshold of >43.5%, AAN must exceed 8.7 g/L when TN is 20 g/L but 13 g/L when TN is 30 g/L, whereas the highest observed AAN was 10.4 g/L. A concentration-based criterion might describe proteolysis differently, but testing it would require replicated data beyond this baseline.

Likewise, the inverse TN-AAN/TN association cannot establish a fermentation mechanism, because TN is the denominator and absolute AAN varied little with TN in nine products. The unusually low AAN of MO2 requires confirmation by replicate measurement: its amino-plus-ammonia nitrogen (13.3 g/L) lay within the 12.2-17.2 g/L range of the other genuine products, but this different method neither confirms nor refutes the AAN value. Subtracting AAN from that result would not give a valid ammonia estimate; in imported product MN6, AAN (10.6 g/L) exceeded the formol result (7.6 g/L). Replicate AAN and direct NH_3-N measurements would be needed before interpreting proteolysis, blending or non-amino nitrogen.

Only 4/10 genuine Nam Ô products met the TCVN AAN/TN benchmark, versus 29/30 marketed Phu Quoc products (Nguyen *et al.*, 2019); differences in product selection, replication and production setting limit attribution to region. Similarly, the wide intervals for the six strict comparators permit practically important differences despite non-significant tests and do not establish equivalence. These observations should guide confirmatory sampling rather than enforcement, particularly because some records predate GI registration.

Raw-fish handling and sensory assessment

Freshness cues are useful traditional knowledge but do not document exposure between landing and salting. Avoidance of iced fish by 11 producers should not be read as evidence that chilling is unsafe; the relevant information is the handling and temperature history. Records of fish source, landing or purchase, receipt, storage and salting would support future tests against validated safety endpoints. Histamine remains a priority because raw-material handling and salt-tolerant microorganisms can influence its formation (Kimura *et al.*, 2001; Yongsawatdigul *et al.*, 2004; Shim *et al.*, 2022; Pham *et al.*, 2025), but no traceable histamine endpoint was measured here, so individual practices cannot be linked to safety outcomes.

Large panellist effects also limit conclusions about consumer preference or GI sensory typicity. Unlike the trained descriptive panel used for Thai fish sauces (Ritthiruangdej and Suwonsichon, 2006), this internal quality panel was not trained for descriptive analysis and showed considerable panellist differences. A trained descriptive panel and a separate consumer study would be needed to distinguish sensory profile, regional identity and preference; the current scores indicate product variation but cannot establish a regional sensory signature.

Proposed controls and study limits

The proposed controls focus on calibrated dosing, batch documentation, pre-salting handling and traceable lot verification; they require prospective testing because producer and product observations were not reliably paired is recommended in Table 6.

The main limitations are single unreplicated determinations on one bottle or lot per product, self-reported practices from a frame of unknown coverage, no producer-product linkage, few comparators sampled mainly in a different year, and incomplete sensory scores with large panellist differences. Histamine, NaCl, pH and microbiological data were not analysed, so safety and full-standard compliance could not be assessed.

This baseline study is documented Nam Ô production practices and the nitrogen composition of commercial products around GI establishment. Operational measurement and documentation, rather than ingredient sourcing, were the main gaps; salt dosing, batch records and pre-salting handling are candidate control points, not proven determinants of quality. Genuine products generally had high TN but variable AAN/TN, and the benchmark counts warrant which confirmed by replicated analysis, particularly for MO2. A pilot combining calibrated dosing, minimum batch records, documented handling and lot testing

should be evaluated with repeated batches and reliable producer-product linkage, to test whether measurable controls reduce avoidable variability while preserving traditional vessel use and sensory diversity.

Table 6. Proposed controls and verification indicators derived from the baseline

Baseline observation	Proposed control	Verification indicator
Mass-only dosing 12/71; volume-only 30/71; mixed/unclear 29/71	Calibrated mass dosing; record salt source and moisture where feasible	Recorded fish:salt mass ratio; NaCl after method verification
Sensory freshness cues; 11/71 avoided iced fish	Record landing, receipt, storage and salting times and temperatures	Complete reception record; validated safety endpoints
Pressing at 1-30 days (n = 14); variable stirring	Record pressing and each stirring event; test allowable process windows	Batch-record completeness; TN and AAN/TN
Outdoor or mixed fermentation in 27/71	Covering, sanitation and suitable containers	Sanitation checklist; microbiological verification
No monitoring in 42/71; no interpretable response in 20/71; colour-led release	Minimum release testing and retained sample for each lot	Lot dossier; TN and AAN/TN; other validated endpoints
Variable regular-grade composition	Clarify grades and compositional claims	Declared versus measured TN; label audit

Acknowledgements

The authors thank the Nam Ô fish-sauce producers who provided production-practice information, the analytical laboratory staff and the sensory panel.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 30 September 2026, Revised: 15 November 2026, Accepted: 17 November 2026)