



Deliverable title	D5.3 Recommendations and guidelines for manufacturing of new sea fennel-based fermented shelf-stable preserves at pilot scale
Deliverable Lead:	CREA-AN
Related Work Package:	WP5
Related Task:	Task 5.3 Pilot-scale manufacturing of fermented and unfermented shelf-stable sea-fennel preserves
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Summary of Deliverable D5.3 – Guidelines for Fermented Sea Fennel Preserves	Deliverable D5.3 translates laboratory successes into practical guidelines for pilot-scale production of fermented, shelf-stable sea fennel preserves - most notably a kimchi-style product enriched with sea fennel sprouts. This document provides detailed instructions on formulation, microbial cultures, processing steps, and quality controls to ensure both safety and sensory excellence. The recommended recipe combines Chinese cabbage, onion, garlic, ginger, chili, paprika, and sea fennel (about 7% of the mix), balancing traditional flavors with the plant's distinctive herbal character. Fermentation is carried out with a carefully selected multi-strain lactic acid bacteria starter (including <i>Lactiplantibacillus plantarum</i>, <i>Leuconostoc pseudomesenteroides</i>, and <i>Weissella confusa</i>), which ensures reliable acidification, microbial safety, and the development of pleasant aromas. Key process steps include brining the cabbage, mixing with inoculated sauce, and controlled fermentation at $5 \pm 1^\circ\text{C}$ for about 26 days, until pH drops below 4.0 and lactic acid exceeds 0.5%. Monitoring of pH, acidity, and microbial populations confirms safety, while sensory panels consistently appreciated the fibrous crunch, herbal aroma, and balanced acidity of the finished product. Packaging in glass jars or polypropylene pouches, with optional mild pasteurization, ensures shelf stability of up to 12 months. For probiotic positioning, live LAB cultures can be reintroduced after

	pasteurization. The guidelines also stress compliance with EU food regulations, HACCP protocols, and clear labeling to build consumer trust.
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Versioning and Contribution History

Version	Date	Modified by	Modification reason
v1.0	20/03/2025	Valentina Melini	First version
V2.0	30/03/2025	Valentina Melini	Comments after peer reviewing process

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1. Guidelines for production of kimchi-like preserve

1 Product Formulation

- Key Ingredients (per 5 kg batch):

	% ingredient	Ingredient (g)
Chinese cabbage	70.53%	3725.34
Onion	4.37%	230.62
Garlic	0.50%	26.61
Ginger	0.50%	26.61
Sea fennel	7.05%	372.53
Red pepper	0.17%	8.87
Paprika	1.85%	97.57
Sugar	0.84%	44.35
Salt	0.76%	39.91
Water	13.43%	709.59

- Ensure raw material consistency (especially sea fennel) by sourcing from the same agricultural lot and verifying freshness and microbiological safety prior to processing.



*Chinese cabbage (*Brassica rapa* subsp. *pekinensis*) ready to be processed for Kimchi production.*

2 Starter Culture Application

- Recommended LAB Consortium:
 - *Lactiplantibacillus plantarum* (PB257)
 - *Leuconostoc pseudomesenteroides* (PB288)
 - *Pediococcus pentosaceus* (FF78)
 - *Weissella confusa* (PB321)
- Inoculation Target: Adjust to 7 Log CFU/g total microbial load in the final mixture.
- Maintain starter culture at -80°C with 3:2 glycerol:MRS broth and activate by culturing at 30°C for 24h before use.

3 Processing Steps

Pre-fermentation

- Salt Brining: Soak cabbage in 10.9% NaCl solution for ~14h.
- Rinsing: Perform two rinses with potable water to reduce excess salt.
- Sauce Mixing: Homogenize all ingredients including sea fennel and inoculated sauce (for started batch).

Fermentation

- Fermentation Vessel: Use sterilized glass jars or food-grade fermentation tanks.
- Batch Size: Minimum 5–10 kg per fermentation unit.
- Fermentation Temperature: Maintain at $5 \pm 1^{\circ}\text{C}$.
- Fermentation Duration: 26 days, monitor pH and TTA throughout.

4 Fermentation Monitoring

- pH Targets:
 - Initial: ~4.9
 - Final (Day 26): ≤ 4.0 (3.86–3.97 achieved)

- Titratable Acidity:
 - Final target: $\geq 0.3\%$ lactic acid ($\geq 0.5\%$ with starter)
- Organic Acids:
 - Lactic Acid: $\sim 0.5\text{--}0.7$ g/100g after fermentation and stabilization
 - Acetic Acid: $\sim 0.1\text{--}0.13$ g/100g

5 **Microbial Safety & Quality Control**

- Microbial Enumeration:
 - Total mesophilic bacteria: up to 8.4 Log CFU/g (normal)
 - LAB (lactococci): higher in started batches (8.3 Log CFU/g)
 - Yeasts, Enterobacteriaceae, Staphylococci, Sulfite-reducers: < 1 Log CFU/g
- Spoilage Organisms:
 - Monitor for Pseudomonadaceae (< 2.7 Log CFU/g by end of fermentation).
- LAB Verification:
 - Confirm survival and dominance using 16S rRNA sequencing.
- Storage Safety Check:
 - No reactivation of pathogens post-fermentation (150-day data suggest shelf stability).

6 **Packaging & Stabilization**

- Packaging Format: Glass jars (1 kg) or food-grade polypropylene pouches (vacuum or MAP).
- Sealing: Ensure airtight closure post-fermentation to maintain anaerobic conditions.
- Optional Mild Pasteurization (if shelf-stability required beyond 6 months):
 - Heat treat at $65\text{--}70^\circ\text{C}$ for 10–15 minutes to inactivate spoilage yeasts or residual pathogens.
 - Consider adding live LAB back post-pasteurization for probiotic claims (if applicable).

7 **Storage & Shelf-Life**

- Storage Conditions:
 - Refrigerated: $4\text{--}8^\circ\text{C}$ (optimal for sensory and microbial quality)
 - Shelf-stable (optional): $\leq 25^\circ\text{C}$ if mild pasteurization applied
- Expected Shelf-Life:
 - Refrigerated: ≥ 6 months
 - Shelf-stable (pasteurized): up to 12 months (monitor acetic/lactic acid profile)

8 **Sensory Evaluation**

- Most Appreciated Attributes:
 - Started Kimchi: sea fennel aroma, vegetable odor, chili flavor, acidity, fibrousness.
- Panel Scores:
 - Global liking ≥ 5.8 for started samples
 - Recommend routine sensory trials every batch to ensure flavor consistency.
- Texture Monitoring:
 - Fibrousness and crunchiness from sea fennel are key textural drivers of consumer acceptance.

9 **Regulatory & Labeling Considerations**

- Comply with EU food fermentation and shelf-stable food regulations.
- Clearly label "fermented vegetable preserve", include:
 - Ingredients
 - Possible probiotics (if claimed)
 - Storage instructions
 - Best before date
 - Pasteurization status (if applicable)

10 Scale-Up Recommendations

- Use fermentation tanks with temperature and anaerobiosis control.
- Implement in-line pH and titratable acidity probes for monitoring.
- Introduce Quality Control checkpoints:
 - Starter viability
 - Pathogen screening
 - Sensory validation
- Establish GMP and HACCP systems tailored to fermented vegetable products.



Kimchi prototype prepared with sea fennel sprouts.

Conclusion

The trial shows that sea fennel is a suitable ingredient for fermented kimchi-style products, offering both microbial stability and sensory appeal. Incorporating a multi-strain LAB starter culture significantly improves acidification, microbial safety, and aroma profile, and should be a standard in pilot-scale production.