

Database Design Report

Food Manufacturing System (CSC 540)

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1 Executive Summary

This report documents the design and implementation of a comprehensive database system for a prepared/frozen meals manufacturing company. The system manages the complete lifecycle of food production, from ingredient sourcing through supplier relationships, recipe versioning, batch production, inventory tracking, and regulatory compliance.

2 Functional Dependencies That Drove the Design

We summarize the key functional dependencies (FDs) that shaped decompositions and keys. Primary/candidate keys are underlined.

Core Reference Entities

- **User**(user_id, first_name, last_name, role_code): $\text{user_id} \rightarrow \text{first_name}, \text{last_name}, \text{role_code}$.
- **Category**(category_id, name, UNIQUE(name)): $\text{category_id} \leftrightarrow \text{name}$ (unique alternative key).
- **Ingredient**(ingredient_id, ingredient_name, ingredient_type): $\text{ingredient_id} \rightarrow \text{ingredient_name}, \text{ingredient_type}$.

Parties

- **Manufacturer**(manufacturer_id, manufacturer_name), with FK Manufacturer \subseteq User: $\text{manufacturer_id} \rightarrow \text{manufacturer_name}$.
- **Supplier**(supplier_id, supplier_name), with FK Supplier \subseteq User: $\text{supplier_id} \rightarrow \text{supplier_name}$.

Product & Structure

- **Product**(product_id, name, manufacturer_id, category_id, standard_batch_units): $\text{product_id} \rightarrow \text{name}, \text{manufacturer_id}, \text{category_id}, \text{standard_batch_units}$.
- **IngredientComposition**(parent_ingredient_id, child_ingredient_id, quantity): $(\text{parent}, \text{child}) \rightarrow \text{quantity}$, with $\text{parent} \neq \text{child}$.

Recipes (Versioned BOM)

- **RecipePlan**(plan_id, product_id, manufacturer_id, version_no, creation_date, is_active; UNIQUE(product_id, manufacturer_id, version_no)): $\text{plan_id} \rightarrow \text{product_id, manufacturer_id, version_no, creation_date, is_active}$.
Note: Product enforces $\text{product_id} \rightarrow \text{manufacturer_id}$, so RecipePlan contains a transitive FD; retained for uniqueness and fast joins.
- **RecipeIngredient**(plan_id, ingredient_id, quantity): $(\text{plan_id, ingredient_id}) \rightarrow \text{quantity}$.

Lots, Batches, Consumption

- **ProductBatch**(batch_id, product_id, manufacturer_id, lot_number UNIQUE, quantity, unit_cost, production_date, expiration_date, plan_id): $\text{batch_id} \rightarrow \text{all}$; lot_number is a candidate key generated by trigger. Product implies $\text{product_id} \rightarrow \text{manufacturer_id}$ (transitive dependency kept).
- **IngredientBatch**(batch_id, ingredient_id, supplier_id, lot_number UNIQUE, quantity_oz, on_hand_oz, unit_cost, expiration_date, intake_date): $\text{batch_id} \rightarrow \text{all}$; lot_number candidate key.
- **BatchConsumption**(product_lot_number, ingredient_lot_number, quantity_consumed, consumption_date): $(\text{product_lot_number, ingredient_lot_number}) \rightarrow \text{attributes}$.

Supplier Formulations (Versioned)

- **SupplierFormulation**(formulation_id, supplier_id, ingredient_id, version_no, pack_size, price_per_unit, effective_period_start_date, effective_period_end_date; UNIQUE(supplier_id, ingredient_id, version_no)): $\text{formulation_id} \rightarrow \text{all}$.
- **SupplierFormulationMaterials**(formulation_id, ingredient_id, qty): $(\text{formulation_id, ingredient_id}) \rightarrow \text{qty}$.

Business Rules

- **DoNotCombine**(ingredientA_id, ingredientB_id): key-only relation with symmetry captured by a check that stores an ordered pair ($A < B$).

3 Normalization Summary (BCNF vs 3NF)

All relations are at least 3NF; most satisfy BCNF. Two tables intentionally remain in 3NF to preserve useful foreign keys and reduce join costs while keeping redundancy controlled by FKS and procedures. Table located in Appendix C.

4 Constraints: Where Implemented and Why

4.1 Enforced in the DB (DDL, Checks, FKS, Triggers)

- **Keys and Referential Integrity:** PKs and FKS across entities (e.g., Product→Manufacturer; IngredientBatch→Supplier/Ingredient; RecipeIngredient→RecipePlan/Ingredient).

- **Domain/Business Checks:** Positive quantities/prices; supplier formulation date order; minimum shelf-life ($\text{expiration} \geq \text{intake} + 90$ days); DoNotCombine stores ordered pair ($A < B$); uniqueness of natural keys (e.g., Category.name), lot numbers, and version triples.
- **Triggers:** Auto-generate lot numbers for ProductBatch/IngredientBatch; block consumption of expired ingredient lots; initialize on-hand quantity on receipt; decrement on-hand after consumption with underflow prevention.
- **Stored Procedures:** `record_production_batch` (atomic batch creation, cost roll-up, consumption posting); `trace_recall` (time-window trace from an ingredient lot to affected product lots); `evaluate_health_risk` (pairwise DoNotCombine check for an input ingredient set).

4.2 Implemented in Application Code (and Justification)

- **Role-Based Access and Menus:** Role is read from `User.role_code`, with routing to MANUFACTURER/SUPPLIER/VIEWER menus (Java). Authorization and UX are application concerns and change frequently; enforcing in code is appropriate.
- **Single Active Recipe Version per (product, manufacturer):** If not enforced in the DB, the application ensures at most one `is_active=TRUE` at a time (set newly active, flip others to `FALSE` in one transaction).

4.3 Could Not Be Fully Expressed in Bare Table Definitions

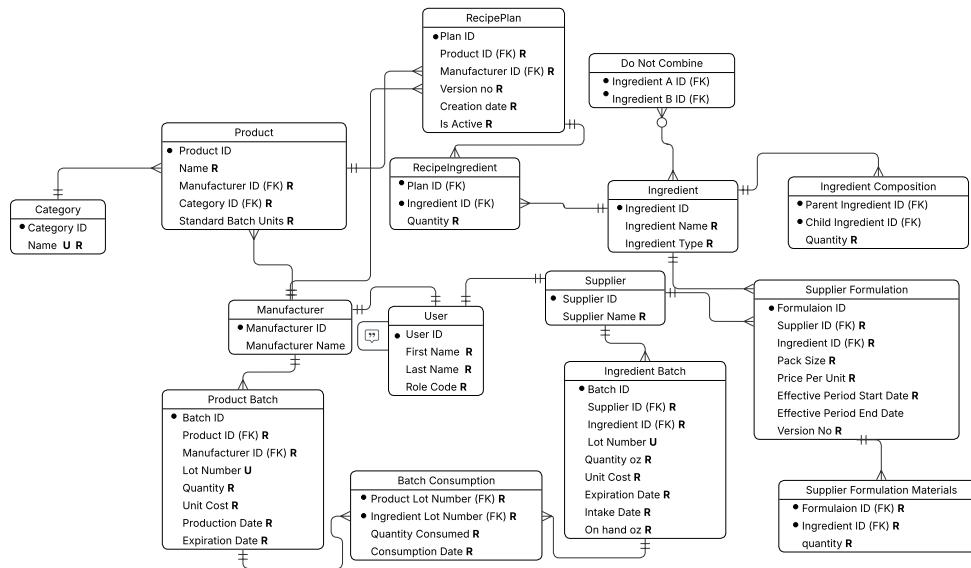
- **Transitive contamination/recall** requires joins and windowing \Rightarrow implemented in `trace_recall`.
- **Pairwise do-not-combine** across an arbitrary set \Rightarrow implemented in `evaluate_health_risk`.
- **Cost roll-up** for product batches \Rightarrow transactional procedure (`record_production_batch`).

5 Design Trade-offs and Rationale

- **BCNF vs 3NF Pragmatism:** Keeping `manufacturer_id` in `RecipePlan` and `ProductBatch` simplifies integrity checks/authorization and reduces joins; redundancy is bounded by FKS and procedures.
- **Versioning as First-Class:** Splitting plans/materials enables auditability and reproducibility (which recipe/supplier formulation version produced a batch).
- **Push Safety & Traceability Into the DB:** Triggers/procedures guarantee enforcement across all clients; UI/roles remain in the application.

Appendix A: ER Diagram

The final entity–relationship (ER) diagram for the Food Manufacturing System is shown below.



Appendix B: Selected DDL / Triggers / Procedures

Listing 1: Example: IngredientComposition DDL

```

1 CREATE TABLE IngredientComposition (
2     parent_ingredient_id INT,
3     child_ingredient_id INT,
4     quantity DECIMAL(10, 2) NOT NULL CHECK (quantity > 0),
5     PRIMARY KEY (parent_ingredient_id, child_ingredient_id),
6     CONSTRAINT parent_ingredient_id_fk FOREIGN KEY (parent_ingredient_id) REFERENCES
7         Ingredient(ingredient_id),
8     CONSTRAINT child_ingredient_id_fk FOREIGN KEY (child_ingredient_id) REFERENCES
9         Ingredient(ingredient_id),
10    CONSTRAINT parent_notequal_child CHECK (parent_ingredient_id != child_ingredient_id)
11 );

```

Listing 2: Example: Prevent expired consumption trigger

```
1 CREATE TRIGGER prevent_expired_consumption
2 BEFORE INSERT ON BatchConsumption
3 FOR EACH ROW
4 BEGIN
5     DECLARE lot_expiration_date DATE;
6     SELECT expiration_date INTO lot_expiration_date
7     FROM IngredientBatch
8     WHERE lot_number = NEW.ingredient_lot_number;
9     IF NOW() > lot_expiration_date THEN
10        SIGNAL SQLSTATE '45000'
11        SET MESSAGE_TEXT = 'You should not consume an expired ingredient lot.';
12    END IF;
13
```

Appendix C: Normalization

Table	Normal Form	Rationale
User, Category, Ingredient, Manufacturer, Supplier	BCNF	PK fully determines non-keys; no transitive FDs. Category also enforces UNIQUE(name) (alt key).
IngredientComposition	BCNF	(parent, child) → quantity; no other FDs.
RecipePlan	3NF	plan_id → product_id, manufacturer_id and Product enforces product_id → manufacturer_id (transitive). Retained for uniqueness (product, manufacturer, version) and fast joins; could omit manufacturer_id to reach BCNF.
RecipeIngredient	BCNF	(plan_id, ingredient_id) → quantity.
ProductBatch	3NF	batch_id → product_id and manufacturer_id; Product implies product_id → manufacturer_id (transitive). Kept for clarity and FK checks; could drop manufacturer_id for BCNF.
IngredientBatch	BCNF	batch_id (and lot_number) determines all.
SupplierFormulation	BCNF	formulation_id (and composite alt key) determines all.
SupplierFormulationMaterials	BCNF	(formulation_id, ingredient_id) → qty.
BatchConsumption	BCNF	(product_lot_number, ingredient_lot_number) → attributes.
DoNotCombine	BCNF	Key-only relation; ordered pair prevents duplicates.

Table 1: Normalization summary. All tables are $\geq 3\text{NF}$; most are BCNF.