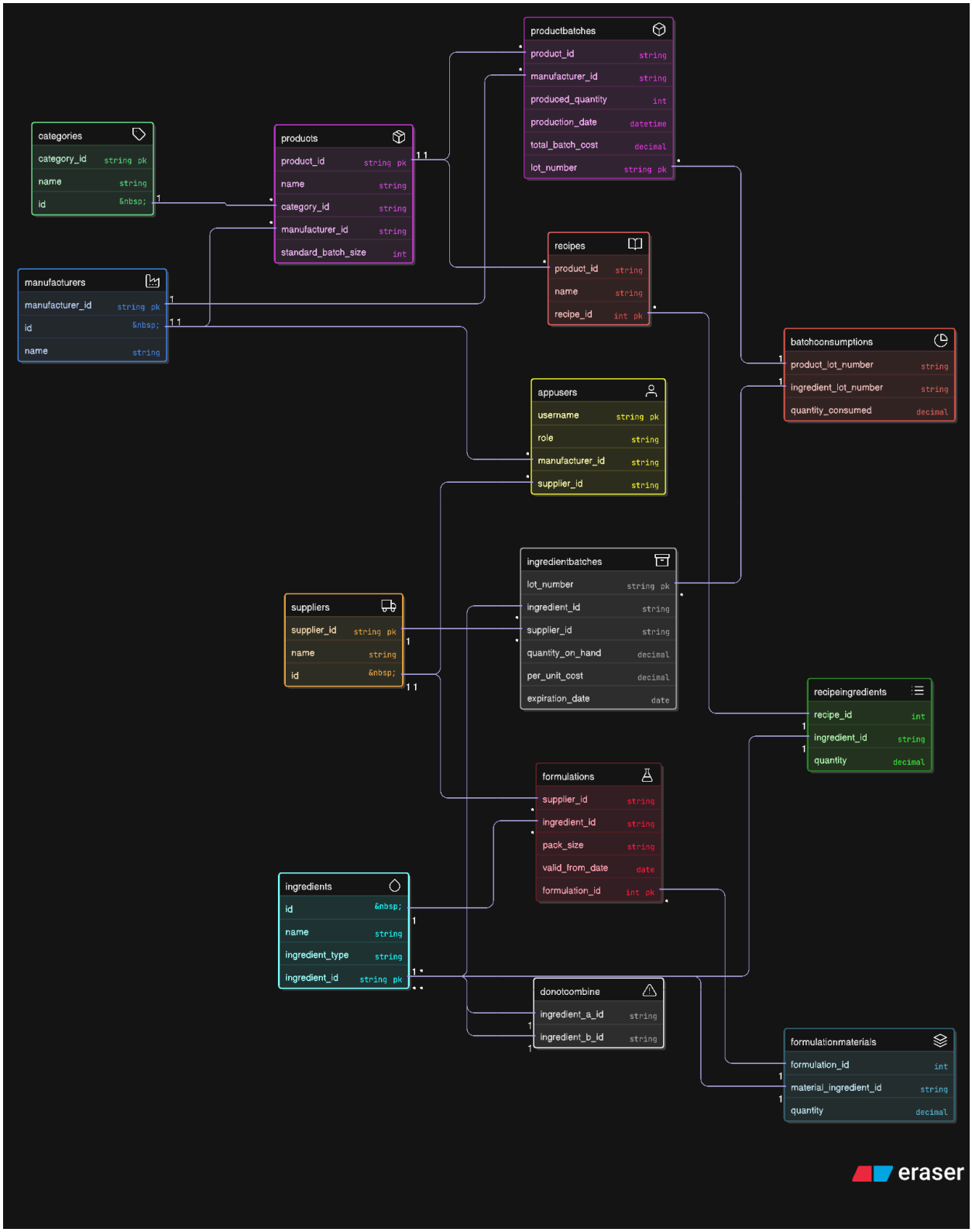
productbatches
product_id string
manufacturer_id string
produced_quantity int
production_date datetime
total_batch_cost decimal
lot_number string pk
categories
category_id string pk
name string
id
products
product_id string pk
name string
category_id string
manufacturer_id string
standard_batch_size int
recipes
product_id string
name string
recipe_id int pk
manufacturers
manufacturer_id string pk
id
name string
batchconsumptions
product_lot_number string
ingredient_lot_number string
quantity_consumed decimal
appusers
username string pk
role string
manufacturer_id string
supplier_id string
ingredientbatches
lot_number string pk
ingredient_id string
supplier_id string
quantity_on_hand decimal
per_unit_cost decimal
expiration_date date
suppliers
supplier_id string pk
name string
id
recipeingredients
recipe_id int
ingredient_id string
quantity decimal
formulations
supplier_id string
ingredient_id string
pack_size string
valid_from_date date
formulation_id int pk
ingredients
id
name string
ingredient_type string
ingredient_id string pk
donotcombine
ingredient_a_id string
ingredient_b_id string
formulationmaterials
formulation_id int
material_ingredient_id string
quantity decimal
eraser

I. Updated Entity-Relationship (ER) Model

The diagram below represents the final, normalized relational schema. This updated model explicitly shows the relationships required for traceability (linking specific ingredient lots to specific product lots) and versioning (Formulations), which were central to the project's complexity.

Analysis of Design Improvements

The final schema is a significant improvement over the initial design, strategically shifting complexity from vulnerable application code to the secure database layer. This design achieves BCNF by eliminating redundancy and enforcing integrity where it matters most.

1. Atomic Lot Creation and Traceability: We replaced simple auto-increment IDs for all inventory items with Composite, Human-Readable Lot Numbers. These keys are automatically generated and enforced by database triggers, guaranteeing uniqueness and consistency for all recall functionality.
2. Centralized Traceability Bridge: The BatchConsumption table was established as the immutable bridge. It links every finished ProductBatch to every consumed IngredientBatch, which is the foundational mechanism for fulfilling the Trace Recall requirement efficiently.
3. Normalization and Consolidation: We unified the old redundant user tables into a single AppUser structure linked by Foreign Keys, eliminating transitive dependencies and simplifying access control, leading to a schema that meets the BCNF standard across all core tables.
4. Database-Enforced Integrity: Critical safety rules (Negative Stock, Health Risk) were moved directly into Stored Procedures and Triggers to ensure they are non-negotiable and protected by the transactional rollback mechanism, preventing data corruption from application errors.