# ONFOODS: A Substitute Recommendation System in Food Recipes

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# Outline

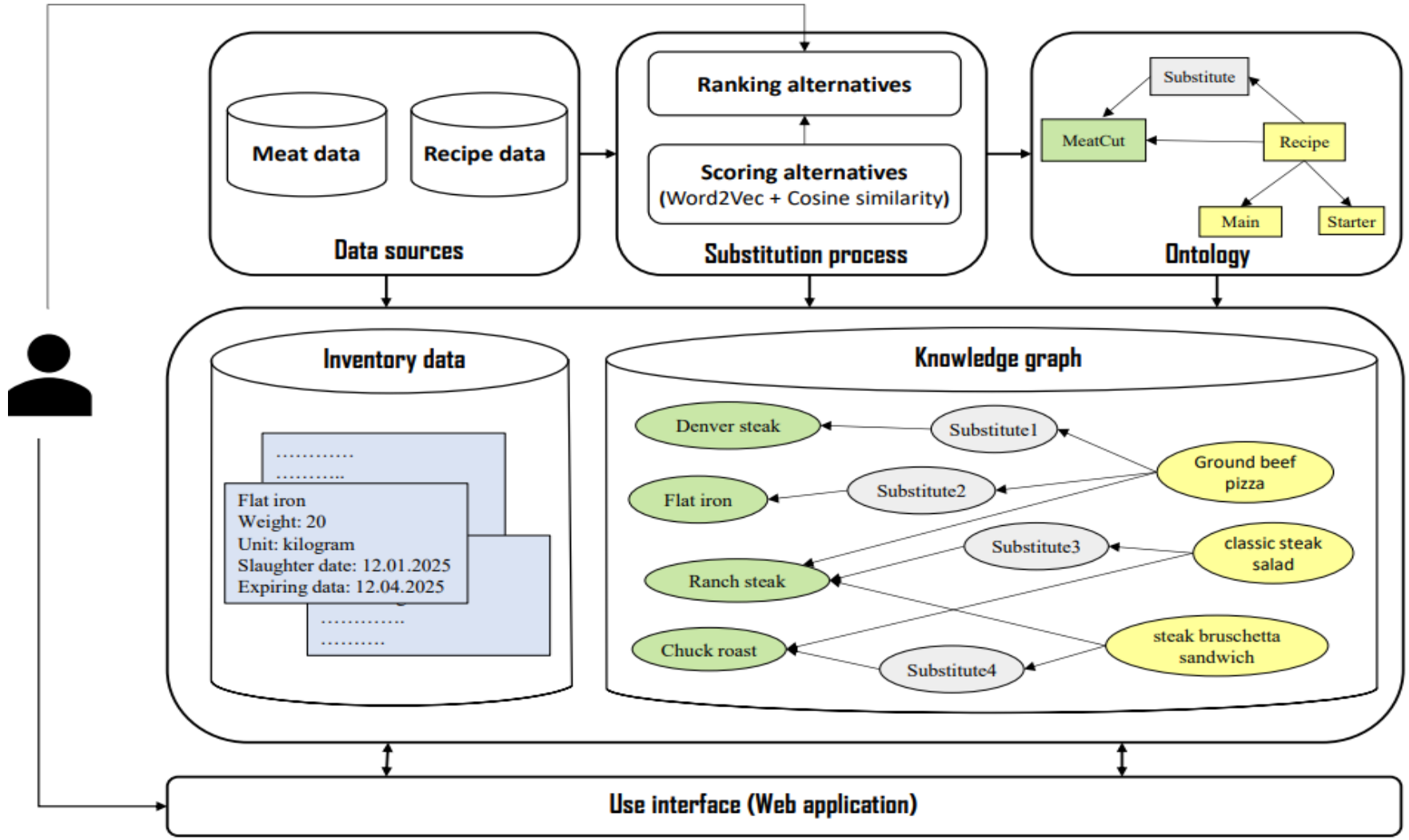
# Motivation & goal

- Food waste remains a major challenge in modern society
- In gastronomy, meat waste is common as only prime cuts are often used in recipes
- Substituting ingredients in cooking recipes has great potential to reduce food waste
- Ontologies and knowledge graphs help model recipes, meat cuts and the relationships between the two.
- Develop a substitute system that uses ontologies and integrates with inventory data.

# Contributions

- Proposing ONFOODS, a recommendation system to find available meat alternatives for recipes
  - Design an ontology to provide a conceptual framework to represent the relationships between meat cuts and recipes
  - Identify suitable alternative meat cuts using similarity and scoring metrics based on nutritional composition and sensory attributes
  - Integrate inventory data into the recommendation system to track the availability of different meat cuts
  - Develop a user-friendly web interface for ONFOODS

# System Design and Architecture of ONFOODS



# Substitution Process

## ❑ Scoring alternatives

- Similarity of ***nutritional compositions*** (protein, lipid, and water) and ***sensory attributes*** (tenderness, texture, and flavor)
- Scoring metrics
  - **Word2Vec model:** map the categorical attribute into numerical vectors
  - **Normalization:** apply Min-Max normalization to all attributes for mapping them to a normalized [0,1] range
  - **Weighted Cosine similarity:** find candidates for alternative meat cuts

$$S(A,B) = \frac{\sum_{i=1}^{n} w_i A_i B_i}{\sqrt{\sum_{i=1}^{n} w_i A_i^2} \cdot \sqrt{\sum_{i=1}^{n} w_i B_i^2}}$$

$$Q_A = Q_B * \frac{100 - Water_B}{100 - Water_A}$$

# Substitution Process

## ❑ Ranking alternatives

- allowing users to refine and customize the suggested alternatives
  - Propose new alternatives
  - Reorder the suggested options
  - Adjust substitution quantities

- Providing interactive process between the ONFOODS system and users
  - Enhances flexibility by integrating user preferences into the system,
  - improving the adaptability and personalization of substitutions

# Ontology

## ❑ Existing Food Ontologies

- **FoodKG** [1] and **FoodOn** [2] provide comprehensive models for food items and nutritional information
- They only offer generic conceptualizations of substitutions
- They do not capture the specific substitution relationships required for practical meat cut recommendations:
  - Nutritional and sensory attributes
  - Explicit substitution quantities.

The development of a tailored ontology is required

1. Haussmann, S. et al, Foodkg: a semantics-driven knowledge graph for food recommendation. In: The Semantic Web–ISWC 2019: 18th International Semantic Web Conference, Auckland, New Zealand, October 26–30, 2019, Proceedings, Part II 18. pp. 146–162. Springer (2019).
2. Dooley, D.M. et al, Foodon: a harmonized food ontology to increase global food traceability, quality control and data integration. npj Science of Food 2(1), 23 (2018).

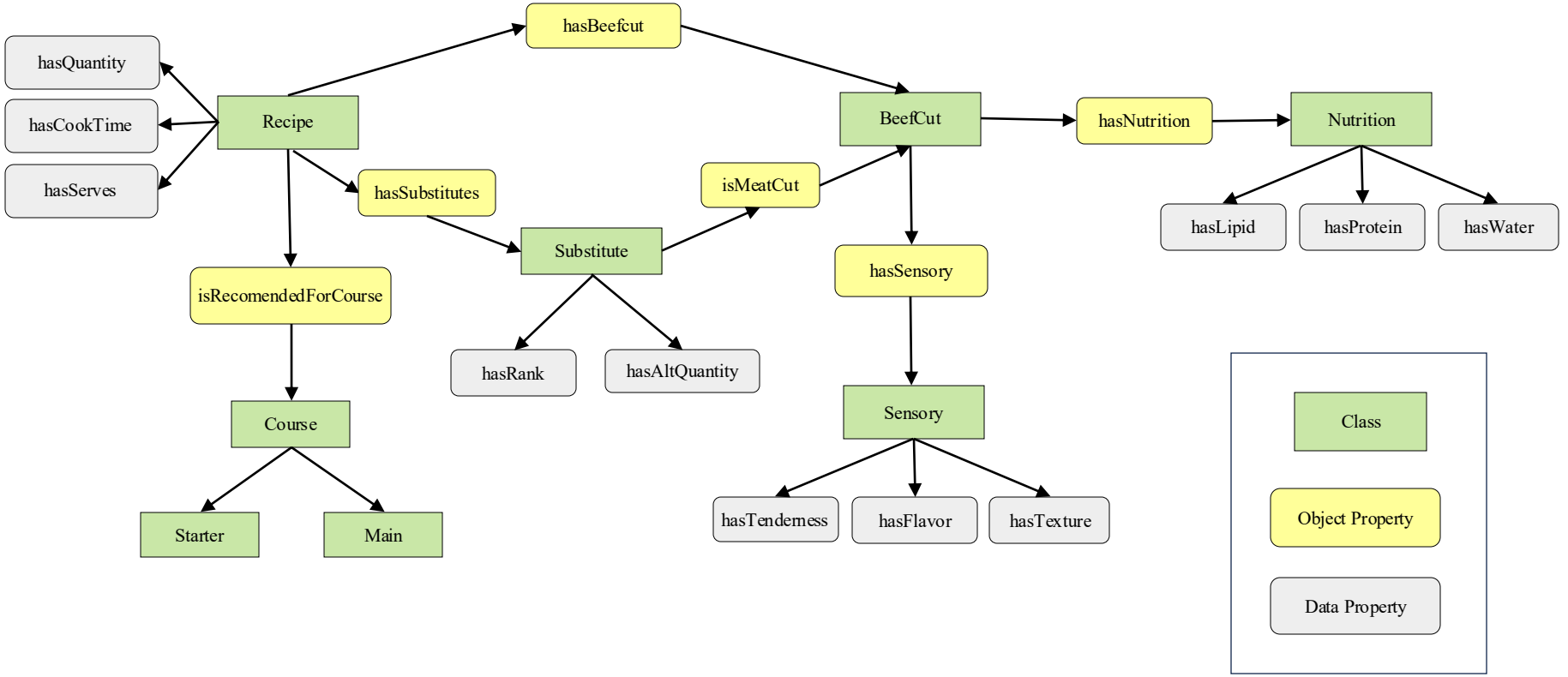
# Ontology

## ❑ Ontology construction (M.López et. al. 2003 [1])

- **Specification:** identifying the purpose of the ontology, defining the scope and objectives of the ontology
- **Knowledge acquisition:** analyzing recipes and meat information for identifying concepts and relationships
- **Conceptualization:** organizing the acquired knowledge into a conceptual model.
- **Implementation:** using ontology languages and tools, such as OWL and Protégé to implement the ontology
- **Validation:** ensuring correctness and consistency of the ontology using reasoners, such as Pellet, integrated in Protégé

1. Fernández-López, M., Gómez-Pérez, A., Juristo, N.: Methontology: from ontological art towards ontological engineering. In: Proceedings of the Ontological Engineering AAAI-97 Spring Symposium Series. pp. 33–40. American Association for Artificial Intelligence (1997)

# Ontology




The ontology is publicly available at https://w3id.org/onfoods/ontology

# Knowledge Graph and Inventory Database

## ❑ Main sources of data

- **The USDA ingredient nutrient database:** providing nutritional information for meat cuts, including protein, lipid, and water content
- **Meat-based recipes from various online recipe sites**: extracting details such as the type of meat cut and its quantity, cooking time, and number of servings

## ❑ Data storage system

- Design a database in PostgreSQL DB for storing the knowledge graph and inventory data about the availability of different meat cuts
- The database schema follows the ontology structure

# User Interface

## ❑ User-friendly Web Application

- Visual clarity, minimal complexity, and intuitive interactions for non-expert users
- Allowing easy access to functionalities like browsing meat cuts, exploring recipes, finding meat cut alternatives, and managing inventory.

## ❑ Implementation

- Using the ASP.NET MVC framework, leveraging Razor for dynamic web pages and PostgreSQL as the database
- The system supports a three-level hierarchy for meat cuts
- Case study: nutrition information of beef cuts, and 200 recipes of real-world use cases in restaurants
- Evaluate performance and responsiveness of the system in various scenarios
- Make publicly available: ONFOODS ( http://onfoods.projects.unibz.it/ )

# Scenario 1 – Browsing Beef Cuts

onfoods

Home | Beef Cuts | Recipes | Inventory | Contact | About

## Cuts Of Beef

- Beef Cuts
  - Brisket
  - Chuck
    - Shoulder tender medallions(0.00kg)
    - Top blade steak(0.00kg)
    - **Arm pot roast (24.75kg)**
    - Chuck eye country-style ribs (5.50kg)
    - Chuck eye steak (12.00kg)
    - Chuck roast (15.00kg)
    - Chuck short ribs (10.00kg)
    - Denver steak (12.00kg)
    - Flat iron (36.00kg)
    - Mock tender steak (17.00kg)
    - Ranch steak (18.00kg)
    - Shoulder pot roast (18.50kg)
  - Flank
  - Loin
  - Plate
  - Rib
  - Round

## Recipes of Arm pot roast

Cowboy beef and hominy stew

Slow cooker braised pot roast with root vegetables

Southwestern beef and bean stew

Smoky chipotle pot roast with cornbread

Instant pot beef biryani

# Scenario 2 – Alternative Beef Cuts

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Home | Beef Cuts | Recipes | Inventory | Contact | About

## Recipe Details

### Classic beef stock

Serves : 6

Category : Main

Cooktime : 30 min

| Select | BeefCut Type | BeefCut Name | Quantity Value (kg) | Availability (kg) |
|---|---|---|---|---|
| ○ | Main | Back ribs | 1.30 | 22.00 |
| ○ | Alternative | Large end | 1.50 | 0.00 |
| ○ | Alternative | Short ribs | 1.00 | 8.00 |

USE

# Scenario 3 – Managing Recipes

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Home | Beef Cuts | Recipes | Inventory | Contact | About

**Add New Recipe**

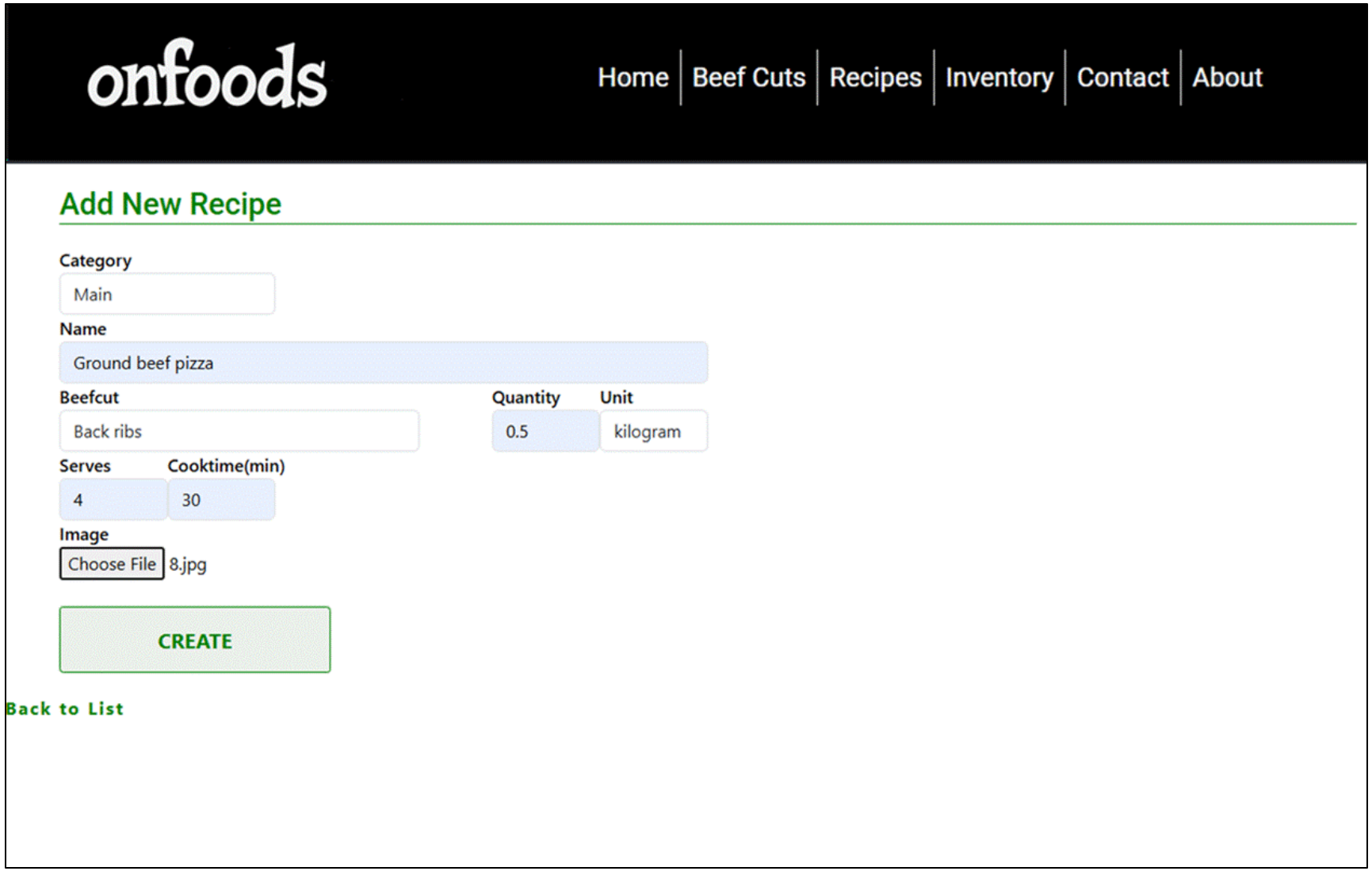
Name : salad Category: Starter

| Recipe Image | Recipe Name | |
|---|---|---|
|  | southwest salad with avocado dressing | Details \| Delete |
|  | classic steak salad | Details \| Delete |
|  | steak & peach salad with lemon dressing | Details \| Delete |
|  | Teriyaki steak salad | Details \| Delete |
|  | Steak caesar salad | Details \| Delete |

First Prev 1 Next Last

Displaying 1 - 5 of 5 item(s)

# Scenario 3 – Managing Recipes



# Scenario 3 – Managing Recipes

onfoods

Home | Beef Cuts | Recipes | Inventory | Contact | About

## Create New Alternative BeefCut

Recipe

Ground beef pizza

Select new Alternative BeefCut: Shoulder tender medallions

Quantity (kg): 0.87

Add

| Main BeefCut | Quantity (kg) | Nutrient Data (Portion :100 gr) | | |
|---|---|---|---|---|
| | | Water (g) | Protein (g) | Lipid(g) |
| Back ribs | 0.50 | 71.50 | 21.20 | 6.59 |

| Rank | Alternative Beefcuts: | Quantity (kg) | Nutrient Data (Portion :100 gr) | | |
|---|---|---|---|---|---|
| | | | Water (g) | Protein (g) | Lipid(g) |
| 3 | Large end | 0.30 | 53.00 | 16.00 | 29.30 |
| 2 | Short ribs | 0.28 | 48.30 | 14.40 | 36.20 |
| 1 | Flat iron | 0.70 | 70.00 | 18.80 | 11.30 |

Save

# Scenario 4 – Managing Inventory

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Home | Beef Cuts | Recipes | Inventory | Contact | About

**Add New Item into Inventory**

Beef cut:

| Beef cut | Slaughter date | Expiry date | Weight | Unit |
|---|---|---|---|---|
| Arm pot roast | 1/7/2025 12:00:00 AM | 8/15/2025 12:00:00 AM | 20.00 | kilogram |
| Flat iron | 11/7/2024 12:00:00 AM | 7/30/2025 12:00:00 AM | 8.00 | kilogram |
| Flank steak | 1/6/2025 12:00:00 AM | 7/20/2025 12:00:00 AM | 10.00 | kilogram |
| Denver steak | 11/7/2024 12:00:00 AM | 8/16/2025 12:00:00 AM | 12.00 | kilogram |
| Ribeye cap steak | 1/7/2025 12:00:00 AM | 8/15/2025 12:00:00 AM | 8.00 | kilogram |
| Back ribs | 1/7/2025 12:00:00 AM | 7/31/2025 12:00:00 AM | 10.00 | kilogram |
| Ranch steak | 1/28/2025 12:00:00 AM | 8/30/2025 12:00:00 AM | 6.00 | kilogram |
| Ranch steak | 1/31/2025 12:00:00 AM | 8/1/2025 12:00:00 AM | 12.00 | kilogram |
| Chuck roast | 11/28/2024 12:00:00 AM | 7/28/2025 12:00:00 AM | 15.00 | kilogram |
| Brisket flat | 10/25/2024 12:00:00 AM | 7/25/2025 12:00:00 AM | 9.00 | kilogram |

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Displaying 1 - 10 of 25 item(s)

# Summery and Future work

## ❑ Summery

- Presenting ONFOODS, a recommendation system for alternative meat cuts that assists chefs in restaurants
- Designing an ontology to model recipes, meat cuts and the relationships between the two
- Integrating inventory data into the recommendation system
- Developing a user-friendly web application for ONFOODS

## ❑ Future Work

- Improving the system using machine learning algorithms to improve the accuracy of meat cut recommendations
- Collaborating with local chefs for suggesting region-specific alternative meat cuts that align with local preferences and sustainability goals

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# Acknowledgment

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# THANK YOU!