Indexing:

Query 4:

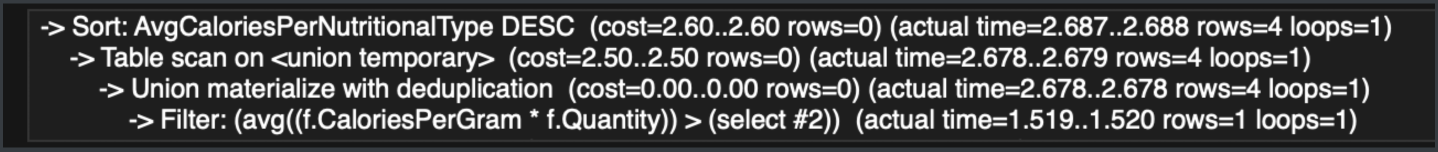
ORDER BY AvgCaloriesPerNutritionalType DESC;

```
EXPLAIN ANALYZE

SELECT f.NutritionType,

●    AVG(f.CaloriesPerGram * f.Quantity) AS
AvgCaloriesPerNutritionalType

FROM Food f

GROUP BY f.NutritionType

HAVING AVG(f.CaloriesPerGram * f.Quantity) > (

  SELECT AVG(f2.CaloriesPerGram * f2.Quantity)

  FROM Food f2

)

UNION

SELECT d.NutritionType,

●    AVG(d.CaloriesPerGram * d.Quantity) AS
AvgCaloriesPerNutritionalType

FROM Drink d
```

```
GROUP BY d.NutritionType

HAVING AVG(d.CaloriesPerGram * d.Quantity) > (

  SELECT AVG(d2.CaloriesPerGram * d2.Quantity)

  FROM Drink d2

)
```

The result shows that:

Index 1: Adding Index on NutritionType in Food and Drink



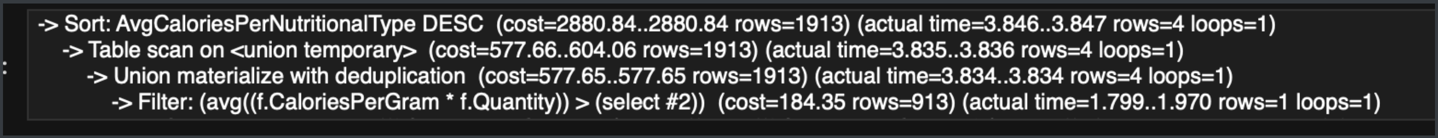
```
-> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2.60..2.60 rows=0) (actual time=2.687..2.688 rows=4 loops=1)
    -> Table scan on <union temporary>  (cost=2.50..2.50 rows=0) (actual time=2.678..2.679 rows=4 loops=1)
        -> Union materialize with deduplication  (cost=0.00..0.00 rows=0) (actual time=2.678..2.678 rows=4 loops=1)
            -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (actual time=1.519..1.520 rows=1 loops=1)
```

Since NutritionType is used in GROUP BY and affects aggregation performance, an index on NutritionType may improve query performance.

CREATE INDEX idx_food_nutrition_type ON Food (NutritionType);

CREATE INDEX idx_drink_nutrition_type ON Drink (NutritionType);

result:



```
-> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2880.84..2880.84 rows=1913) (actual time=3.846..3.847 rows=4 loops=1)
    -> Table scan on <union temporary>  (cost=577.66..604.06 rows=1913) (actual time=3.835..3.836 rows=4 loops=1)
        -> Union materialize with deduplication  (cost=577.65..577.65 rows=1913) (actual time=3.834..3.834 rows=4 loops=1)
            -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (cost=184.35 rows=913) (actual time=1.799..1.970 rows=1 loops=1)
```

we discover that these indexes are not effective on this query on time.

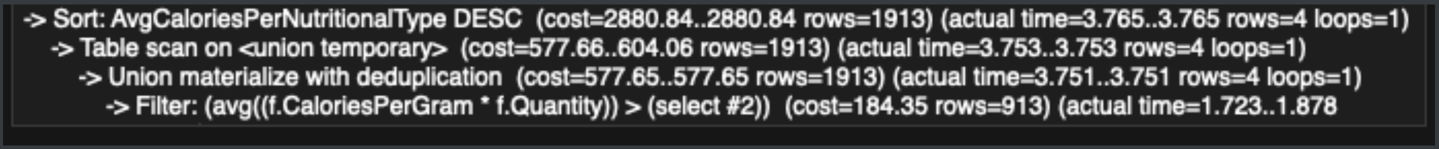
Index 2: Adding Index on CaloriesPerGram in Food and Drink

Since CaloriesPerGram is used in calculations within the HAVING clause, an index on this attribute might reduce the cost of filtering.

CREATE INDEX idx_food_calories_per_gram ON Food (CaloriesPerGram);

CREATE INDEX idx_drink_calories_per_gram ON Drink (CaloriesPerGram);

Result:



```
-> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2880.84..2880.84 rows=1913) (actual time=3.765..3.765 rows=4 loops=1)
    -> Table scan on <union temporary>  (cost=577.66..604.06 rows=1913) (actual time=3.753..3.753 rows=4 loops=1)
        -> Union materialize with deduplication  (cost=577.65..577.65 rows=1913) (actual time=3.751..3.751 rows=4 loops=1)
            -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (cost=184.35 rows=913) (actual time=1.723..1.878
```

we discover that these indexes are not effective on this query on time.

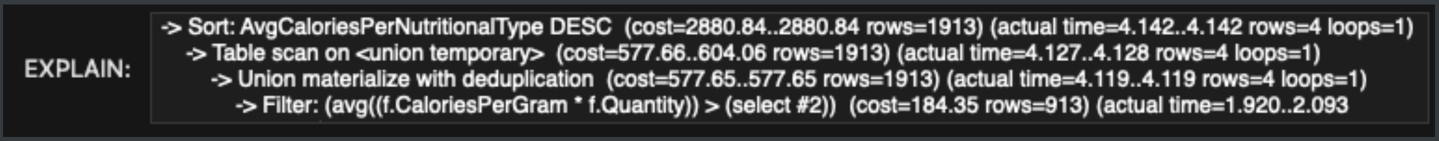
##### index 3: Combined Index on NutritionType and CaloriesPerGram in Food and Drink

composite indexes on both NutritionType and CaloriesPerGram if these attributes appear frequently in queries.

CREATE INDEX idx_food_nutrition_calories ON Food (NutritionType, CaloriesPerGram);

CREATE INDEX idx_drink_nutrition_calories ON Drink (NutritionType, CaloriesPerGram);

result:



```
EXPLAIN: -> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2880.84..2880.84 rows=1913) (actual time=4.142..4.142 rows=4 loops=1)
             -> Table scan on <union temporary>  (cost=577.66..604.06 rows=1913) (actual time=4.127..4.128 rows=4 loops=1)
                 -> Union materialize with deduplication  (cost=577.65..577.65 rows=1913) (actual time=4.119..4.119 rows=4 loops=1)
                     -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (cost=184.35 rows=913) (actual time=1.920..2.093
```

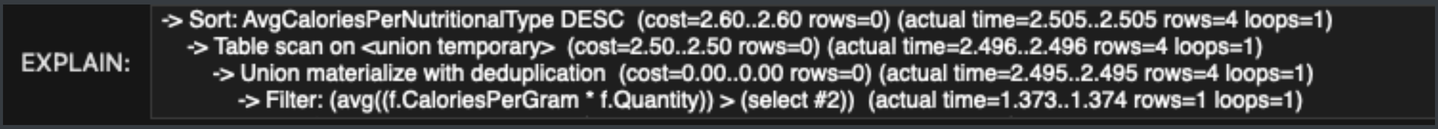
From all these 3 results, we discover that these indexes are not effective on this query on time.

```
Query 3:
```

```sql
SELECT f.NutritionType,

•    AVG(f.CaloriesPerGram * f.Quantity) AS
AvgCaloriesPerNutritionalType

FROM Food f

GROUP BY f.NutritionType

HAVING AVG(f.CaloriesPerGram * f.Quantity) > (

  SELECT AVG(f2.CaloriesPerGram * f2.Quantity)

  FROM Food f2

)

UNION

SELECT d.NutritionType,

•    AVG(d.CaloriesPerGram * d.Quantity) AS
AvgCaloriesPerNutritionalType

FROM Drink d

GROUP BY d.NutritionType

HAVING AVG(d.CaloriesPerGram * d.Quantity) > (

  SELECT AVG(d2.CaloriesPerGram * d2.Quantity)
```

```sql
      FROM Drink d2

    )

    ORDER BY AvgCaloriesPerNutritionalType DESC;
```

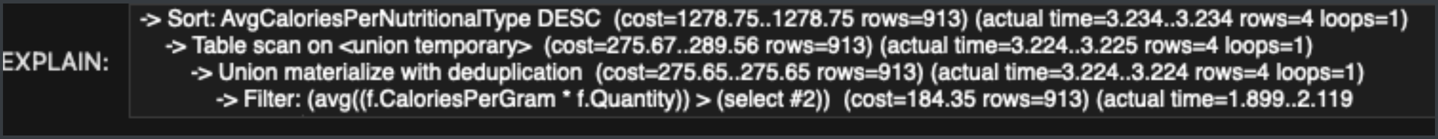
Baseline:



```
EXPLAIN:
-> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2.60..2.60 rows=0) (actual time=2.505..2.505 rows=4 loops=1)
    -> Table scan on <union temporary>  (cost=2.50..2.50 rows=0) (actual time=2.496..2.496 rows=4 loops=1)
        -> Union materialize with deduplication  (cost=0.00..0.00 rows=0) (actual time=2.495..2.495 rows=4 loops=1)
            -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (actual time=1.373..1.374 rows=1 loops=1)
```

Index 1: Single Index on NutritionType in Food

CREATE INDEX idx_food_nutrition_type ON Food (NutritionType);



```
EXPLAIN:
-> Sort: AvgCaloriesPerNutritionalType DESC  (cost=1278.75..1278.75 rows=913) (actual time=3.234..3.234 rows=4 loops=1)
    -> Table scan on <union temporary>  (cost=275.67..289.56 rows=913) (actual time=3.224..3.225 rows=4 loops=1)
        -> Union materialize with deduplication  (cost=275.65..275.65 rows=913) (actual time=3.224..3.224 rows=4 loops=1)
            -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (cost=184.35 rows=913) (actual time=1.899..2.119
```

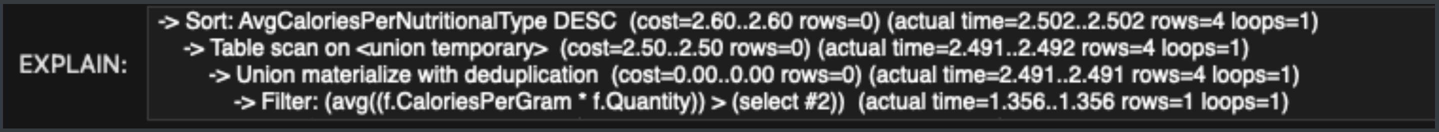
We saw that it has no effect.

```sql
    CREATE INDEX idx_food_calories_per_gram ON Food (CaloriesPerGram);

    CREATE INDEX idx_drink_calories_per_gram ON Drink (CaloriesPerGram);
```

CREATE INDEX idx_food_calories_per_gram ON Food (CaloriesPerGram);

CREATE INDEX idx_drink_calories_per_gram ON Drink (CaloriesPerGram);

Index 2: Single Index on CaloriesPerGram in Food and Drink

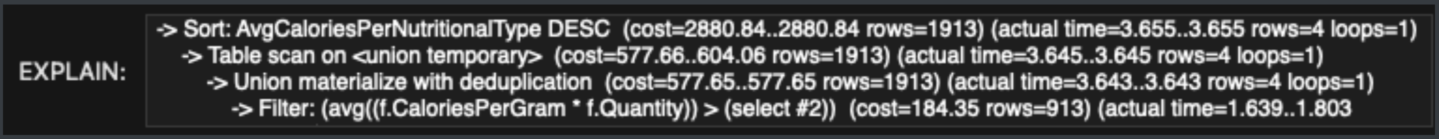


```
EXPLAIN: -> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2.60..2.60 rows=0) (actual time=2.502..2.502 rows=4 loops=1)
           -> Table scan on <union temporary>  (cost=2.50..2.50 rows=0) (actual time=2.491..2.492 rows=4 loops=1)
             -> Union materialize with deduplication  (cost=0.00..0.00 rows=0) (actual time=2.491..2.491 rows=4 loops=1)
               -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (actual time=1.356..1.356 rows=1 loops=1)
```

We saw that it has slightly effect.

Index 3: Combined Index on NutritionType and CaloriesPerGram in Food and Drink

```sql
CREATE INDEX idx_food_nutrition_calories ON Food (NutritionType,
CaloriesPerGram);
CREATE INDEX idx_drink_nutrition_calories ON Drink (NutritionType,
CaloriesPerGram);
```



```
EXPLAIN: -> Sort: AvgCaloriesPerNutritionalType DESC  (cost=2880.84..2880.84 rows=1913) (actual time=3.655..3.655 rows=4 loops=1)
           -> Table scan on <union temporary>  (cost=577.66..604.06 rows=1913) (actual time=3.645..3.645 rows=4 loops=1)
             -> Union materialize with deduplication  (cost=577.65..577.65 rows=1913) (actual time=3.643..3.643 rows=4 loops=1)
               -> Filter: (avg((f.CaloriesPerGram * f.Quantity)) > (select #2))  (cost=184.35 rows=913) (actual time=1.639..1.803
```

We saw that it has no effect.

Conclusion: indexing is not so effective on these two queries might because the special stucture of the query, that is, to use the union with group by.