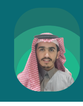
From Waste to Wealth: A New Pathway for Food Waste Management in KSA


Hussain Y Alqahtani
Chemical Engineering


Khaled M Alqahtani
Chemical Engineering


Abdulrahman Alamarani
Industrial and Systems Engineering


Abdullah Alqahtani
Industrial and Systems Engineering


Abdullah Alshahrani
Industrial and Systems Engineering

INTRODUCTION

Elevator Pitch

Food businesses face a problem with surplus/wasted food. So, for food businesses, who wants to reduce the food waste, NIEMA is an application that allows food businesses to offer near-expiry food to be sold at discounted price. Unlike other applications, NIEMA is also taking care of the expired food, especially bread, to prepare it for biogas production

Problem Statement

In response to Saudi Arabia's significant food waste challenge, our project at King Fahad University of Petroleum and Minerals aims to innovatively reduce total food waste, especially focusing on bread reduction, through a %50 s goal of a'2030 waste, aligning with Vision comprehensive approach that includes converting discarded bread into valuable biogas feedstock, optimizing pre-treatment station locations, developing a collection mathematical model and introducing the 'Niemah' digital platform as a connecting bridge for businesses and consumers, enabling the sale of items nearing expiration and fostering a sustainable and circular economy

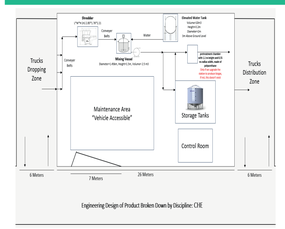
CONSTRAINTS

1. Collection Logistics : Effective collecting logistics are essential
2. Transportation: Suitable trucks and logistical plans
3. Volume and Capacity: Optimizing container capacity and collection frequencies
4. Bread Should be stored for less than 3 days before going to the station
5. Bread must be size reduced to a range of 40-10 mm
6. Bread moisture content has to be in the range of %70 to %80
7. pH level for slurry bread must be in the range of 6.5 to 7.5

SPECIFICATIONS

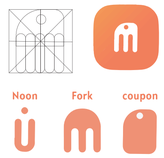
1. Number of available food items
2. Distance between customers and retailers does not exceed 5 kilometers
3. The food offered should be at least %20 discounted price
4. Offered food should have at least one day to its expiration date
5. Size Reduction of Expired Bread (40mm)
6. Bread Slurry Moisture Content (%75)
7. pH Range 6.5

PROTOTYPE DESIGN



Pre-Treatment Station Design

- Dropping Zone
- Size Reduction
- Moisture Control
- Pumping & Storage
- Distribution Zone



Niema App prototype Identity

The coupon represents the discount offered. The fork indicates food. path The Arabic letter"ن" is part of the Arabic name of the application, which is "نعمة" which represents the target audience.

Bakeries' interface

Streamlines surplus bread pickup for food businesses.

Features an intuitive order system for easy management.

Offers a seamless connection to the pre-treatment process.

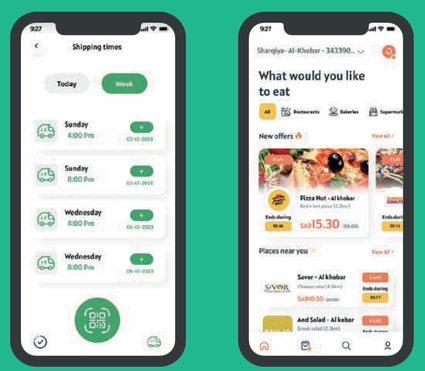
Optimizes collection routes using data analytics.

Customers' interface

Enables informed choices on discounted items.

Tailors choices based on consumer preferences.

.Enhances the user experience for consumers



TESTING & VALIDATION

Pre-Treatment Station

Moisture Control Assumptions:

- 12 ton/day of wasted bread= 0.5 ton/hour
- Initial Moisture Content %20, Shredded to 40mm

The Procedure Used to Find the Needed Water Addition is Overall Mass Balance While considering the average density of wasted bread to be 500 kg/m3

- 275 kg/h of water to the mixing vessel to achieve a %75 moisture content in the bread.
- The volume of the vessel at least 2.1 m3

Elevated Water Source & Slurry Pumping:

- velocity of the water at the mixer head is approximately 5.42 m/s.
- centrifugal slurry pump, Pump capacity in terms of volumetric flow rate, is approximately 4.004m³/h.

Equations Used:

$$P_1 + \frac{1}{2}\cdot\rho\cdot v_1^2 + \rho\cdot g\cdot z_1 = P_2 + \frac{1}{2}\cdot\rho\cdot v_2^2 + \rho\cdot g\cdot z_2 \quad \Delta p = f_D\frac{L}{D}\frac{\rho V^2}{2}$$

Ph Measurements:

- Arabic Bread 50 g + Toast Bread 25 g + Bun Bread 25 g "Initial Moisture %20"
- 220 mL of distilled water

Experimental Results:

Time (Minutes)	pH
1:00	7.011
2:00	6.741
3:00	6.682
4:00	6.644
5:00	6.607
6:00	6.572
7:00	6.596
8:00	6.581
10:00	6.576
12:00	6.583
14:00	6.564

Optimum location module

- 20 different bakeries in Khobar, Dhahran, and Dammam have been selected as potential locations for container distribution.
- Target plants for supply are Tadweer and WASCO.
- Identified three possible locations for the pre-treatment station.
- Implemented a module to evaluate and select the best location among the three for the pre-treatment station.

Mathematical :module

Where:
I = is the total number of bakeries and plants i=22,..,1.
J = is the total number of potential locations j=1,2,3.
W = the weight of each bakery/plant. For bakeries w=1, for plants w=3.
ai = the x-coordinate of location of bakery/plant i.
bi = the y-coordinate of location of bakery/plant i.
X and Y = the x-coordinate and y-coordinate of the optimal location.
Lj = 1, if the station is located at site j. and 0 other wise.

$$Min\ z = \sum_{i=1}^{n} w_i[|x - a_i| + |y - b_i|]$$

Subjected to:

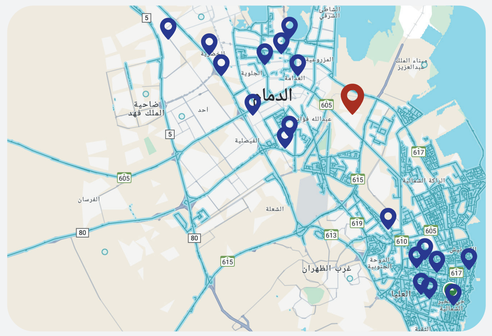
$L_1 + L_2 + L_3 = 1$
$L_1 * (x - 50.13904546) = 0$
$L_1 * (y - 26.39778873) = 0$
$L_2 * (x - 49.98126135) = 0$
$L_2 * (y - 26.24600871) = 0$
$L_3 * (x - 49.94940314) = 0$
$L_3 * (y - 25.94446418) = 0$
$X, Y \geq 0$
$L_1, L_2, L_3 \in \{0,1\}$

Results

Optimal location is the First Industrial City of Dammam, with the following coordinates and values:

$Objective\ Value = 8.417348$
$X = 50.13904546$
$Y = 26.39778873$
$L_1 = 1$
$L_2 = 0$
$L_3 = 0$

The map shows the selected location(red) and the bakeries location(blue)



Collection module

- Build mathematical formulation for the problem.
- Selected a small sample of 20 large bakeries in Dammam, Al Khobar, and Dhahran for model testing.
- Accurate distances calculated in kilometers using Google Maps, considering different streets for customer i to customer j and vice versa.
- Demand categorized based on expected volume: 1000 kg for large factory bakeries, 500 kg for medium-sized, and 100 kg for small bakeries.
- Truck capacity assumed to be 3500 kg.

Mathematical module:

Parameter and variables:
Qi: the demand from bakery i in kg.
QK: the demand from bakery K in kg
Ui: is the accumulated served volume for bakery i in KG.
N= number of customer (1,…,N)
N1 is the treatment station (depot)
dij=distance from the point i to point j .
Xij = 1 if customer i to j is in route otherwise 0; note that XKj =1
XKJ =1 if customer k to j is in route otherwise 0
TCAP= maximum truck capacity in kg
NUMTR=Number of trucks needed to serve the customers

$$min \sum_{i,j}^{n} d_{ij} x_{ij}$$

$$\sum_{K>1} X_{KK} = 0$$

$$\sum_{i \neq k, i \neq 1} X_{ik} = 1$$

$$\sum_{j \neq k, j \neq 1} X_{kj} = 1 \qquad \forall k$$

$$Q_k \leq U_k \leq TCAP \ , \forall k$$

$$U_k \geq U_i + Q_k - \mathrm{TCAP} + \mathrm{TCAP}\cdot(X_{ki} + X_{ik}) - (Q_k + Q_i)\cdot X_{ki} \quad \forall i,k\ i \neq k, i \neq 1$$

$$U_k \leq \mathrm{TCAP} - (\mathrm{TCAP} - Q_k)\cdot X_{1k}\ , \qquad k = 1$$

$$U_k \geq Q_k + \sum_{i=2}^{N} Q_i \cdot X_{ik} \qquad \forall\ k$$

$$NUMTR = \sum_{i=2}^{N} Q_i \Big/ TCAP$$

$$\sum_{j=2}^{N} X_{1j} \geq NUMTR$$

$$X_{ij} \in \{0,1\}, dij > 0, Qi > 0, U_K > 0, Q_i > 0\ , NUMTR \in Z^+$$

PROCESS FLOW

Niemah APP

1

- With an interface designed for both consumers and food businesses, particularly bakeries, the platform ensures a smooth and user-friendly experience. **It allows bakeries to sell soon-to-expire items at discounted prices, reducing food waste, while enabling consumers to access high-quality food at lower costs.**
- The Niemah Digital Channel Prototype includes a specialized interface for bakeries, allowing them to directly connect with the Niemah pre-treatment process. **This feature streamlines surplus bread collection by enabling bakeries to place orders through the platform.**

Bakery Container Collection & Transportation

2

- The containers are specifically designed for bakeries to manage wasted bread effectively. They are constructed using stainless steel material and offer a voluminous capacity of 1900 liters. The design takes into consideration the ease of handling, as well as the convenience of cleaning. **These containers are intended to meet the specific needs of bakeries in a professional and efficient manner, providing a reliable solution for managing bread waste.**
- **Logistics Optimization for Efficient Collection:** Minimize travel distances for collection teams, ensuring the overall efficiency of the surplus bread collection process. Consider key logistical factors such as the proximity to bakeries to enhance the effectiveness of the collection operations.

Pre-Treatment Process

3

- Size Reduction to Increase the Surface Area
- Mixing With Water To Achieve %75 Moisture Content, because it gives the microbes the moisture they need to break down the organic waste and effectively create biogas.
- The type of feed that will be produced at the pre-treatment station is referred to as "slurry bread." The slurry bread is typically rich in organic matter and carbohydrates derived from the bread waste. **It provides a nutrient source for the microorganisms involved in the anaerobic digestion process, which produces biogas**

CONCLUSION

- The addition of 275 kh/h "Based on the assumptions" will give us the needed moisture content.
- The choice of the shredder is a "single shaft shredder" that will provide a 40mm outlet size. For a 4 m3/h of a bread and water mixture, a c centrifugal slurry pump will be used.
- Using Bernoulli's equation, Elevated water source will minimize the power usage.
- The Lab Experiment verifies that the pH level is within the needed range.
- The collection module minimizes travel distances for container pick-up routes.
- Niemah app links consumers to food businesses, facilitating the sale of near-expiry items at discounted prices and streamlining the collection of bread containers from bakeries.
- The station could collaborate with an existing biogas production plant, or with the government to reduce food waste towards 2030 vision.