Food availability in the Gaza Strip during operation *Swords of Iron*, October 2023 to August 2024: a retrospective analysis

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# Abstract

To be written

# Key words

Gaza, occupied Palestinian territories, war, conflict, insecurity, food, caloric, nutrition

# Introduction

The population of the Gaza Strip has experienced seven decades of protracted conflict and almost 16 years of enforced restrictions on trade and the movement of people and goods, including food [1]. Since the 7 October 2023 Hamas attacks, Israel has conducted large-scale aerial bombing and ground operations in Gaza under the umbrella of operation *Swords of Iron*, resulting in at least X deaths and approximately 1.9M people displaced [2].

Prior to the current war, 62% of Gazan households experienced food insecurity [3] and ≈1.7M people depended on humanitarian food and cash assistance [3] provided by UNRWA and WFP, which covered up to 48% of poor households’ caloric intake [4]. Nutritional outcomes at population level reflected an energy-sufficient but insufficiently diverse diet. The burden of both acute and chronic malnutrition in 6 to 59 months old (mo) children was low (wasting 1%, stunting 9%, and underweight 2% [5, 6]) and adult (18 to 69yo) prevalence of obesity was high (28%) [7]. Prevalence of exclusive breastfeeding in infants <6mo was 42% [5] with high adoption of infant formula feeding. Only 43% of children aged 6 to 23mo enjoyed minimum dietary diversity [5], anaemia (haemoglobin <11.5 g/dL) affected 25% of first-year schoolchildren [6] and 41% of pregnant and lactating women [*ref??]*, while 11% of households had a poor food consumption score [5–8].

The ongoing military operation has severely damaged or destroyed much of the food system, including cropland area (43% damaged by February 2024 [9]), the fishing fleet, flour mills and bakeries, supply chains and food markets. Physical access to agricultural land and fishing and supply chains have also been impeded. Simultaneously, Israel has placed further restrictions on aid flows and distributions, closing all but two southern entry points into Gaza up to May 2024 and rejecting multiple consignments for ostensible security reasons [10]. While most of the population of the northern Gaza City and North Gaza governorates had fled south by December 2023, those who did not appeared largely cut off from aid: the United Nations Relief and Works Agency for Palestine Refugees (UNRWA) last delivered food to the north on 23 January 2024 [11], being then barred from further deliveries [12], while the United Nations World Food Programme (WFP) ceased its food convoy operations to the north on 20 January [13], only resuming these on a limited basis in March. In December 2023 the Integrated Food Security Phase Classification (IPC), a multistakeholder initiative that conducts evidence and consensus-based analyses of acute food insecurity and malnutrition to inform global emergency response, classified 25% of the population in the northern governorates as experiencing catastrophic acute food insecurity [14], updating this projection to 55% in March 2024 [10]. Community middle-upper-arm circumference screenings of children 6 to 23mo in the north suggested an acute malnutrition prevalence of 16% in January and 31% in February [14].

Table 1 summarises the evolution of key food system indicators over the first 11 months of the war, indicating an objective deterioration in food security. Despite these signals, successive IPC reports acknowledge a dearth of quantitative evidence on actual food availability over time in Gaza, hampering accurate analysis. For example, in March 2024 Oxfam claimed that the population in northern Gaza had only 230 Kcal per person-day available, while Israeli academics, working with data by the Israeli Ministry of Defense’s Coordination of Government Activities in the Territories (COGAT) agency, put this figure at 3160 during Jan-Apr 2024 (https://assets-eu.researchsquare.com/files/rs-4454344/v1/3c6b0d3f-a733-4cad-9fca-16ee358b8a54.pdf?c=1719412619). Since May 2024, re-opening of crossings into Gaza and increased food deliveries have appeared to mitigate food insecurity and avert further deteriorations in nutritional status. Add latest IPC report To support objective assessment of the war’s conduct and civilian impacts, we retrospectively estimated food availability in Gaza based on available information on all possible food sources. In a separate paper we will explore how caloric availability may have affected nutritional outcomes.

# Methods

## Study population and period

We considered the entire population within the Gaza Strip, stratified into a northern (North Gaza, Gaza City governorates) and central-southern region (Deir al Balah, Khan Younis, Rafah). As of March 2024, an estimated 250,000 individuals remained in the north [15], from approximately 1,200,000 pre-war [16]. Our analysis spans 7 October 2023 to 31 August 2024. Gaza’s age and sex population distribution in 2023-2024 were obtained from UNFPA projections [17]. Household size and age-sex composition at baseline were based on the 2017 census [16].

## Trucking data

### Data sources

From 7 October 2023 to 5 May 2024, UNRWA systematically monitored and published the composition of all trucks crossing into Gaza [18]. Since 6 May 2024, following the Israeli Defence Force (IDF)’s Rafah operation, crossings are controlled by Israel and the UN can longer collect comprehensive trucking data, though it continues to publish these; private/commercial freight has become particularly challenging to obtain information on. We downloaded the UNRWA trucking line list (<https://www.unrwa.org/what-we-do/gaza-supplies-and-dispatch-tracking>) covering the analysis period. Separately, COGAT publishes a simpler dataset (<https://gaza-aid-data.gov.il/main/>) with breakdown by date, route (land, sea, air), category of consignment (‘food’ is one of these) and metric tons (mt) consigned. Until Israel re-opened the northern Erez and Erez West crossings, trucks must perforce leave south-central Gaza to resupply the north. We reconstructed the number of these trucks over time based on published information and data shared by the UN World Food Programme. As no data on content was available, we simulated their caloric equivalent by repeatedly sampling from the empirical distribution of calories per truck obtained from the UNRWA dataset (see below and Figure 6, Annex). The remaining trucked food was attributed to the central-southern region.

### Management of the UNRWA dataset

We excluded 5 observations with missing item description, leaving 35,379 records, of which 25,242 (71.3%) from the period before the Rafah operation. For 86.5% (29,611) records no weight was provided, and instead the number of pallets was given; the latter’s standard load is 637.5 Kg [10] and should not exceed 750 kg [19, 20]). After merging multiple records with the same truck ID, 35,330 individual truck records were compiled. Most trucks carried a single item, but 5071 (14.3%) carried up to nine items. We represented likely variability in actual pallet weight as a uniform distribution ranging from 0.8 to 1.2 of the standard weight. We also allowed the relative proportion of each item, for multi-item trucks, to vary randomly.

After harmonising alternative food item nomenclature, we applied each item’s caloric equivalent by consulting the NutVal 4.1 application (<https://fscluster.org/sites/default/files/documents/nutval-4.1_0.xls>) or the United States Department of Agriculture’s FoodData Central database (<https://fdc.nal.usda.gov/index.html>). When the item description was non-specific, we made the following assumptions: for ‘food baskets’, ‘food cartons’, ‘food parcels’, ‘ration packs’ and ‘ready meals’ the sender was almost always one of the following organisations: the UN World Food Programme, UNRWA, the Palestinian Red Crescent, or World Central Kitchen (WCK) and its partner ANERA; we looked up or asked organisations to share their food basket or parcel compositions, and applied the mean of parcels from the above organisations for a small minority of other senders. For ‘food items’, ‘canned food’ and ‘cooked food’, we assumed the mean of specific (canned or any other) items sent by the originator if this was one of the above organisations, or the mean across all senders otherwise. Specialised food items used to prevent or treat malnutrition (ready-to-use food, therapeutic milk, supplementary foods) were omitted from trucking data and instead sourced from the Nutrition Cluster [21]. While there are reports of aid being rejected by the IDF even after a truck crossed into Gaza, we assumed that food would have been allowed through [22].

## Other food sources

### Existing household stocks of humanitarian food aid

Pre-war, UNRWA provided 1675 Kcal/day to 620,310 and 902 Kcal/day to 389,680 registered refugees in Gaza, distributed every three months CITE, while WFP assisted 20% of non-refugee households (about 243,000 people) with food parcels: households were classed into four vulnerability tiers, which received 204,000 , 433,000, 837,000 and 1,054,000 Kcal every three months, respectively; we assumed that an equal proportion of WFP-assisted households belonged to each tier CITE. Altogether, humanitarian food assistance amounted to approximately 871 Kcal/day/person considering the whole population living in Gaza. We allocated this amount based on the pre-war share of food aid recipients in each region (49.4% in the north and 50.6% in the south).

We assumed that at baseline UNRWA- and WFP-assisted households would have held between 0-100% of their last UNRWA or WFP rations, as detailed above, depending on the last distribution’s timing. We distributed this amount over the first three months of the crisis but discounted it for the increasing percentage of damaged or destroyed residences in each region, as a linear interpolation of approximately monthly estimates provided by UNOSAT based on satellite imagery CITE : we assumed this percentage to be a proxy of loss of household stocks.

### Existing humanitarian warehouses

The exact content of food available in UNRWA warehouses on 7 October 2023 was shared by UNRWA. For WFP, we sourced data on existing warehouses’ location and storage capacity [23], which we transformed into a caloric equivalent based on the WFP ration’s contents; because warehouse capacity was given as a range (e.g. 100-500 MT), we sampled from this range during simulation (below). We assumed that all warehoused food became available, despite reports of Israeli airstrike damage and looting.

### Existing private stores

Let be the mean pre-war caloric intake per person-day (see below for its estimation). We assumed that the fraction of not met through food aid pre-war, would have been entirely sourced from private markets, stocked from agricultural output within Gaza (see below) and retail food trucked in. By around 18 December 2023, the last of these private stores were reported to have emptied [24], suggesting that they would have had no more than 72 days of stock. Therefore, we assumed that stores would have been able to supply for 72 days based on their baseline stock, but discounted this amount, as above, for the reported proportion of operational stores in each region over time [25], which could reflect stockouts as well as military damage; as above, we linearly interpolated sequential data points of store operationality.

### Agriculture and livestock sector

Pre-war, agricultural output fulfilled about 12% of [4], but as the war progressed, a greater proportion of cropland was reported damaged [26], with remote sensing analysis by the Food and Agriculture Organisation reporting 8% damage by December 2023, 28% by January 2024, 43% by February and 57% by May (16)[27][28]. We thus assumed roughly that the agricultural sector would have fulfilled 10-15% of during the first two months of the crisis, with this proportion declining to 4-7% by May 2024 as a linear interpolation of percent cropland damage.

### Airdrops and boat deliveries

Since 2 March 2024, countries including the United States, the United Arab Emirates, Egypt, Jordan, Germany, France and the United Kingdom carried out numerous airdrops, mostly over northern Gaza. We reviewed press releases by each country’s armed forces to extract weight and caloric equivalents of each airdrop. Where caloric equivalent was not provided (9 instances), we assumed the same caloric equivalent as the WCK food parcels. Where medical supplies were reported to be part of the airdrop (5 instances), we assumed food accounted for 70% of total weight. We also included a single instance of boat delivery by WCK and partners on 15 March 2024 and all deliveries by the Joint Logistics Over-the-Shore (JLOTS) maritime corridor set up by the United States, which operated intermittently between 16 May and 17 July 2024.

## Estimating caloric intake over time

### Combining all food sources and population denominators

We combined all of the above food sources into a simulation, sampling randomly from the ranges of unknown quantities during each run. During each daily timestep, we depleted the starting caloric balance by (see above) and added new calories from all the available sources. We assumed that people would continue to consume if sufficient food were available, or as much as possible if not. Accordingly, to estimate , i.e. the actual daily mean intake in region on day , we estimated the combined daily calories available from all plausible food sources, and divided this by , estimated population at that time, constraining .

The movement of population in each region was tracked over time based on monthly United Nations Office for Coordination of Humanitarian Affairs (OCHA) reports [16] [29] [30] [31], with simple interpolation to connect available data points.

## Ethics

We did not use data from human participants.

# Results

## Quantity of food trucked in

As shown in Figure 1, the number of food-transporting trucks that entered the Gaza Strip appeared consistently lower than the pre-war baseline of 150-180 per day. While the number of trucks rose steadily between late October 2023 and early January 2024, it then fell again, only reach pre-war levels in late April 2024. Since the Rafah operation in early May and its subsequent inability to consistently register truck consignments, UNRWA reported a consistently lower and declining number of trucks, albeit nearly all food-transporting.

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Figure 1. Mean daily number of trucks carrying some food and no food, by week, according to UNRWA data. The pre-war range is as reported by International Phase Classification assessments [14]. Percentages below each bar indicate the proportion of the total weight of items trucked in that consisted of food. Bars are shaded more lightly after the Rafah operation on 5 May 2024, to indicate likely underreporting in the UNRWA dataset.

From mid-November 2023 there was a consistent discrepancy between food weight equivalent trucked-in according to UNRWA and COGAT, though the respective trends were similar (Figure 2). Considering the period when UNRWA was directly monitoring all truck arrivals (before 6 May 2024), the number of food-transporting trucks registered by UNRWA was 17,924, while COGAT’s database contains 17,924 records: it is unclear whether these are all individual trucks. The median (inter-quartile range) estimated weight of food per food-transporting truck was 14.0mt (8.3 to 16.6) per UNRWA, while each COGAT food record featured a median 20mt. Notably, COGAT data show evidence of possible digit heaping or crude approximation, as nearly all food consignment values were reported as exactly 15, 20 or 30mt (Figure 2). As COGAT data do not specify consignment contents, a direct comparison of the two data sources in terms of Kcal cannot be established.

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Figure 2. Comparison of food weight equivalent trucked into the Gaza Strip by week, according to UNRWA and the COGAT agency of the Israeli Ministry of Defence. The inset graph shows the distribution of number of metric tonnes per food consignment through any land crossing, according to COGAT data.

## Diversity of food trucked in

A tabulation of individual food items trucked-in and their frequency of importation is provided in the Annex, Table S2. As shown in Figure 3B, a large proportion of food records during the first few months of the war did not have detail on specific foods. After mid-December 2023 around 70-80% of food could be grouped into a food category. Cereals and baked goods accounted for about 40-50% of food weight. There was relatively little evolution in terms of the contribution of other food categories. There was, however, some fluctuation in the mean caloric value of food (Figure 3A), with the lowest values estimated over the first six weeks of 2024.

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Figure 3. Panel A: estimated mean caloric value of 1 Kg of food trucked into the Gaza Strip, by week. Panel B: proportional contribution of different food categories to the total weight of food trucked in, by week. Only weeks before the Rafah operation are shown. Source: UNRWA dataset.

## Contribution of different food sources

While in south-central Gaza about 75% total Kcal available was trucked-in, this proportion was a lot lower in the north (Table 1). We estimated that stocks present on 7 October 2023 accounted for about half of all Kcal available in the north, but only one fifth in south-central Gaza. The combination of air drops and seaborne deliveries delivered about 3-4% of total calories available in the north and a negligible percentage in south-central Gaza.

Table 1. Estimated number of Kcal (in billions) available to the population of northern and south-central Gaza, by period and source. Figures in parentheses report the 95% confidence interval (only shown if the food source featured any uncertainty) and column-wise percentages, relative to the total calories available.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **source** | **Period before the Rafah operation (5 May 2024)** | | **Entire analysis period** | |
| north | south-central | north | south-central |
| agriculture | 66.4  (46.6 to 96.7, 25.5%) | 57.9  (40.6 to 84.3, 6.1%) | 87.4  (60.5 to 128.4, 30.8%) | 76.2  (52.7 to 112.0, 5.9%) |
| air / boat drops | 8.1  (n/a, 3.1%) | 0.5  (n/a, 0.1%) | 11.0  (n/a, 3.9%) | 14.4  (n/a, 1.1%) |
| household stocks | 33.4  (1.7 to 65.4, 12.8%) | 40.1  (2.0 to 80.7, 4.2%) | 33.4  (1.7 to 65.4, 11.8%) | 40.1  (2.0 to 80.7, 3.1%) |
| market stocks | 71.4  (47.4 to 107.9, 27.5%) | 113.0  (72.1 to 175.2, 12.0%) | 71.4  (47.4 to 107.9, 25.2%) | 113.0  (72.1 to 175.2, 8.7%) |
| trucks | 48.7  (46.5 to 51.0, 18.7%) | 708.8  (565.6 to 837.9, 75.0%) | 48.7  (46.5 to 51.0, 17.1%) | 1031.8  (842.9 to 1202.2, 79.4%) |
| warehouse stocks | 32.1  (n/a, 12.3%) | 24.1  (n/a, 2.6%) | 32.1  (n/a, 11.3%) | 24.1  (n/a, 1.9%) |
| total | 260.1  (182.3 to 361.2, 100.0%) | 944.5  (704.9 to 1202.8, 100.0%) | 284.0  (199.1 to 395.8, 100.0%) | 1299.6  (1008.2 to 1608.7, 100.0%) |

## Per-capita caloric availability

We estimate that the mean number of calories available per person-day began to decline by early November 2023 in the north, where it remained below the recommended daily intake threshold for about 12 weeks (Figure 4), recovering steeply in March 2024 to pre-war baseline levels. In the south-central governorates a more moderate reduction was estimated, with only 3 weeks below the recommended intake (note however that we do not account for food losses, distribution problems or inequity in allocation: see Discussion). Estimates for the north are subject to considerable uncertainty, reflecting parameter uncertainty introduced into the simulation.

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Figure 4. Estimated number of Kcal available per person-day in the north and south-central areas of Gaza, by week. Shaded areas indicate the 80% (darker shade) and 95% (lighter shade) uncertainty interval around the point estimate. The yellow dotted horizontal line denotes the theoretical mean caloric requirement per person-day, based on Gaza’s pre-war demographic characteristics. Point estimates are shaded more lightly after 5 May 2024 to denote data uncertainty and thus likely underestimation following the Rafah operation.

# Discussion

## Main findings

## Limitations

## Conclusions

# Acknowledgments

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# Annex

## Timeline of food system disruptions

Table 2. Timeline of food system disruption in Gaza, pre-war and October 2023 to August 2024.

NEEDS TO BE UPDATED

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Pre-war** | **2023** | | | **2024** | | | | | | | |
| Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug |
| **Food production** | | | | | | | | | | | | |
| Cropland area damaged |  |  |  | 8%  [28] | 28%  [27] | 43%  [9] |  |  |  |  |  |  |
| Damage to fishing fleet |  |  |  |  | 70%  [32] |  |  |  |  |  |  |  |
| Operational bakeries | 97  [33] | 5/24 WFP bakeries operating  [27]  11 bakeries struck  [34] |  |  | 15 bakeries operating  [33] |  |  |  |  |  |  |  |
| Flour mills |  |  | Last mill destroyed [35] |  |  |  |  |  |  |  |  |  |
| **Food assistance and importation** | | | | | | | | | | | | |
| Crossings into Gaza | ADD | 7-20 Oct: none  From 21 Oct: Rafah [18] |  | From 17 Dec: Rafah, Kerem Shalom  [18] |  |  |  |  |  |  |  |  |
| **Food access** | | | | | | | | | | | | |
| Food and beverage consumer price index | 110  [25] | 121  [25] | 133  [25] | 193  [25] | 225  [25] |  |  |  |  |  |  |  |
| **Food utilisation** | | | | | | | | | | | | |
| Poor food consumption score (<28) | 11%  [8] |  | North Gaza, Gaza city: 81% [36]  Deir al Balah, Khan Younis:  39% [36]  Rafah:  39% [36] |  |  | North Gaza, Gaza city: 88%  Deir al Balah, Khan Younis:  53%  Rafah:  48%  CITE |  |  |  |  |  |  |
| Poor child dietary diversity,  6-23mo  (≤2 food groups in the previous 24h) | ADD |  |  |  | 90% (add location) CITE |  | North Gaza, Gaza city: 100%  Deir al Balah: 82%  Khan Younis:  97%  Rafah: 91%  CITE |  |  |  |  |  |

## Baseline adult caloric intake

A graph of different colored lines

Description automatically generated

Figure S5. Untransformed and log-transformed distributions of daily caloric intake by age and sex, 2020 [1].

## Food items trucked into Gaza

Table S3. Number of times different food items were trucked into Gaza according to the UNRWA database, before and after the 5 May 2024 Rafah operation.

| **item** | **before Rafah operation** | **post-Rafah operation** |
| --- | --- | --- |
| apples | 28 | 0 |
| baby food | 5 | 0 |
| baby milk | 12 | 1 |
| beans | 64 | 3 |
| biscuits | 424 | 290 |
| bread | 17 | 55 |
| bulgur | 2 | 0 |
| cake | 75 | 31 |
| candies | 9 | 32 |
| canned beans | 60 | 11 |
| canned chickpeas | 1 | 0 |
| canned corn | 2 | 4 |
| canned food | 288 | 60 |
| canned hummus | 2 | 0 |
| canned vegetables | 2 | 0 |
| carrot | 1 | 4 |
| cerelac | 3 | 0 |
| cheese | 232 | 52 |
| chicken | 3 | 0 |
| chicken broth | 1 | 0 |
| chickpeas | 24 | 38 |
| chips | 37 | 28 |
| chocolate | 7 | 12 |
| clarified butter | 16 | 40 |
| coconut | 1 | 0 |
| coffee | 38 | 163 |
| cooked food | 1 | 0 |
| cooking oil | 150 | 63 |
| corn | 3 | 10 |
| cream | 1 | 0 |
| croissants | 115 | 0 |
| dairy products | 2 | 0 |
| dates | 141 | 3 |
| dried koshary | 1 | 0 |
| eggplant | 1 | 0 |
| eggs | 53 | 232 |
| fava beans | 3 | 0 |
| fish | 4 | 0 |
| flour | 5575 | 1958 |
| food | 9 | 3 |
| food baskets | 1 | 0 |
| food cartons | 1 | 0 |
| food items | 3326 | 1105 |
| food parcels | 4484 | 962 |
| food supplies | 1 | 0 |
| frozen chicken | 184 | 474 |
| frozen meat | 86 | 174 |
| frozen okra | 5 | 0 |
| frozen vegetables | 7 | 0 |
| fruits | 8 | 1257 |
| garlic | 30 | 3 |
| grapes | 2 | 0 |
| green beans | 1 | 1 |
| halawa | 50 | 2 |
| honey | 22 | 1 |
| hummus | 16 | 3 |
| instant noodles | 36 | 0 |
| jam | 8 | 13 |
| juice | 85 | 410 |
| jute leaves | 2 | 0 |
| kiwi | 1 | 0 |
| legumes | 32 | 69 |
| lemons | 19 | 27 |
| lentils | 180 | 89 |
| lentils soup | 1 | 0 |
| luncheon | 178 | 0 |
| meat | 5 | 0 |
| melon | 5 | 1 |
| milk | 155 | 105 |
| noodles | 68 | 367 |
| nuts | 4 | 133 |
| oatmeal | 1 | 0 |
| oil | 246 | 366 |
| onions | 98 | 119 |
| oranges | 37 | 2 |
| pasta | 176 | 31 |
| peanuts | 1 | 0 |
| pears | 1 | 0 |
| peas | 2 | 0 |
| pineapples | 1 | 0 |
| pistachios | 12 | 4 |
| pomegranates | 3 | 0 |
| potatoes | 139 | 91 |
| raisins | 8 | 0 |
| ration packs | 1 | 0 |
| ready | 62 | 0 |
| ready meals | 5 | 0 |
| rice | 436 | 200 |
| sage | 9 | 0 |
| salt | 66 | 239 |
| sardine | 1 | 0 |
| sauce | 35 | 35 |
| semolina flour | 25 | 29 |
| sesame seeds | 1 | 0 |
| soda | 23 | 0 |
| spices | 8 | 36 |
| starch | 6 | 24 |
| strawberries | 1 | 0 |
| sugar | 247 | 444 |
| sweet potatoes | 1 | 0 |
| tahini | 4 | 15 |
| tea | 13 | 58 |
| thyme | 2 | 0 |
| tomato paste | 16 | 0 |
| tomato sauce | 61 | 48 |
| tomatoes | 5 | 11 |
| tortilla | 2 | 0 |
| tuna | 84 | 9 |
| vegetable oil | 8 | 0 |
| vegetables | 13 | 716 |
| watermelon | 1 | 24 |
| yeast | 33 | 16 |
| yogurt | 4 | 0 |

## Caloric equivalent of trucks

A graph of a graph

Description automatically generated

Figure S6. Distribution of estimated Kcal per truck, according to UNRWA data.