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An example of a convergent mixed-methods analysis to examine food security: the case of Popokabaka in the Democratic Republic of Congo

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Abstract

Background Food insecurity is alarming in all four dimensions—availability, access, utilization, and stability—in Popokabaka, DR Congo. In such cases, a unique indicator may not help to develop adapted and local long-term actions. A comprehensive analysis of food insecurity is needed. We aimed to examine the burden and extent of food insecurity and suggest integrative pathways using a mixed approach for transformative actions at the local level.

Methods We designed a convergent parallel mixed-methods study with four-level data sources collected in Popokabaka: (1) *a household food survey* (using the Household Food Insecurity Access Scale (HFIAS), a Household Dietary Diversity Score (HDDS) and the Food Consumption Score (FCS), (2) *a market food census* (assessing food availability and cost per 100 g), and (3) *an exit food market survey* (assessing buyers' food choices and client satisfaction), and (4) *on-farm qualitative study among food producers* (exploring challenges and opportunities). Descriptive statistics from our quantitative data were triangulated with themes emerging from qualitative data.

Results Popokabaka experienced severe food access insecurity (89%), poor food consumption (40.7%), and low dietary diversity (30.2%) at the household level. The quantitative findings at the household level were linked to market characteristics and farmer-reported themes under three pathways: *poor diet quality*, *culturally grounded diet*, and *risk perception*.

Conclusions The focus should be on improving livestock development, developing adapted communications about nutrition to change established dietary habits, and engaging the government and all stakeholders to empower local communities for improved food security.

Keywords Food insecurity, Mixed methods, Market, Household, On-farm

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Introduction

The progress toward Sustainable Development Goal 2 (SDG 2), which aims to ensure that all people all the time have physical, social, and economic access to sufficient, safe, and nutritious food and aims at eradicating all forms of malnutrition, has stagnated globally (1). According to the 2022 Global Report on Food Crises (GRFC) [2], global hunger levels remain alarmingly high due to a confluence of crises such as COVID-19, climate change, and conflicts [3] that continue to worsen malnutrition among the most vulnerable groups (people in developing countries, rural settings, and poorer households, as well as children) [4]. The 2022 State of Food Security and Nutrition in the World Report (SOFI) [5] estimated that worldwide, between 702 and 828 million people were affected by hunger, an increase of 150 million since 2019. In 2021, approximately 2.3 billion people were moderately or severely food insecure, representing 11.7% of the global population [5]. Concurrently, the 2021 Global Nutrition Report [6] estimated that 149.2 million children under 5 years of age were stunted, and 45.4 million were wasted in 2021.

Food security is an established determinant of people's nutrition [7] and encompasses four complex dimensions: availability, access, utilization, and stability [8]. Each dimension has its indicators and estimation methods, often leading to different conclusions and making a common interpretation difficult [9]. Notwithstanding the progress made on new analytic metrics development, there has been, until now, no consensus on a unique or best indicator that could capture all dimensions of food security at the community level [10–13]. The Integrated Food Security Phase Classification (IPC) [14], a multi-stakeholder initiative, has suggested a combination of consensus-based indicators, which, unfortunately, use a country-level scale that is difficult to implement at the community level. Designing actions and priorities that improve food security at the community level depends on reliable, complete, and meaningful information [15]. Moreover, such actions may also require that different assessment approaches are mixed to include quantitative and qualitative aspects that incorporate the local context.

Mixed methods allow the harmonization of commonalities and divergences through different analytic methods [16]. They offer researchers and policy-makers a significant advantage in achieving deeper explorations and fostering a comprehensive and linked analysis of the situation resulting from multiple approaches triangulation [16, 17]. Few studies have considered mixed methods in examining food security, and most have considered only one dimension of food security (food access) while not exploring other food chain sites within the same community. Limon et al. [18] in 2017 used a qualitative approach

when they considered the household level and mixed the Food Consumption Score (FCS), a quantitative indicator that assesses household access to food, with smallholders' perception. Using an exploratory sequential mixed methods design (QUAL → quant) in the U.S. in 2021, Swindle et al. [19] translated interview themes into survey items to explore the generalizability of their qualitative findings.

The Democratic Republic of Congo (DRC) continues to rank among the poorest countries in the world (175 out of 189 countries based on the 2021 Human Development Index) [20], with one of the world's highest rates of food insecurity [5]. Sporadic sensitive interventions to enhance food security have been implemented across the country. However, decisions must be made and priorities established based on analyzing the situation that integrates all dimensions of food security and different levels of the food chain. However, the burden and extensibility of food insecurity have not been adequately documented when considering each community within its context. Rural states hold a big part of the Food Insecurity burden in DRC [21]. Popokabaka is characterised as a rural Congolese region where food security is expected to be affected in all four dimensions without any war crisis. Thus, it represents a community with common Congolese rural lifestyle challenges. The region also has nutrition evidence [22–28] at the community level to serve local policy decisions.

In the present study, we attempted a parallel convergent mixed analysis to examine food security at different levels of the food chain (household level, market level, and farm level) within the Popokabaka community, DRC, to orient the development and implementation of adapted actions in that area.

Methods

Study design

We designed a parallel convergent mixed-method study [16] that integrates quantitative and qualitative approaches, which were applied at the same time (April–August 2019) within the same study area. Quantitative approaches included assessment of household food access and utilization at the household level (based on a *household survey*), as well as food availability (based on a *market food survey*) and client satisfaction (based on an *exit survey*) at the market level. The qualitative inquiry explored challenges faced by local food producers through focus group discussions and interviews with key informants. The rationale for mixing the two approaches [29] was to bring together valuable contributions from the household and rural food-market contexts as well as explanations about agriculture production in Popokabaka.

Study site

The study was conducted in the Popokabaka Health Zone, a rural region located in Kwango Province, DRC (Fig. 1). The region extends over 6949 km² (5° 22' 49.26'' S–5° 22' 49.26'' S, 16° 20' 26.16'' E–16° 20' 26.16'' E) and 200,000 inhabitants, including 38 000 children. The Kwango River, in which many affluent rivers flow, separates the region into two parts. Geographical access is limited due to no paved roads. The community’s culture relies on cassava agriculture, as people consume cassava roots and leaves as staple foods. Raising livestock, poultry, and fishing are not practiced as much as cassava growing. There are six official local food markets in Popokabaka, which take place twice a week on regular and set days. Three markets are located on the western side of the Kwango River (Ngasa, Ibuka, and Kisoma), and three are on the eastern side of the river (Citepopo, Imbela, and Kiamfu Kinzadi). Usually, people walk several kilometers to reach the official local market to sell their agricultural production or stock household foods. Several organizations, such as the Food and Agriculture Organization (FAO) [30], CARITAS [31], Congodorpen [32], and ISCO [28], have led projects assisting farmers and providing equipment to support better agricultural

production over the last 10 years. However, the situation remains of concern, particularly in some areas with limited road access: Konzo, a food-based neurotoxic motor disease, is prevalent in the region, mainly affecting women and children [26, 27, 33]. Malnutrition and micronutrient deficiencies are also common among children under five [22–24].

Targeted population, sampling techniques, and assessment of variables’ criteria

Table 1 summarizes the target study population, sampling techniques, and assessment criteria for each component.

Data collection technique

Quantitative data

All quantitative data were collected through semi-structured interviews using digital questionnaires through the Survey CTO application on an Android tablet; the data were then uploaded to a cloud survey for timely feedback during fieldwork.

- *The household survey:* Based on 432 households, the data gathered included information about household demographics, food stock, Household Food Insecu-

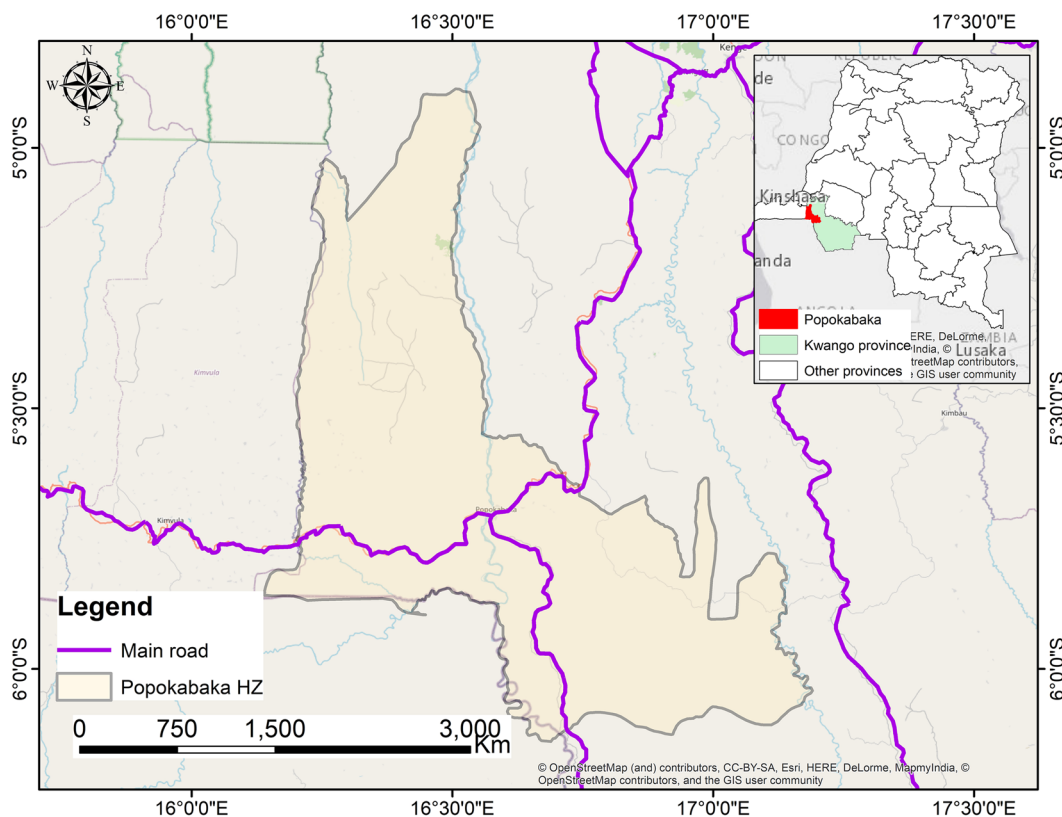


Fig. 1 Location of Popokabaka Health Zone. Source: shapefile downloaded from the Humanitarian Data Exchange (<https://data.humdata.org/dataset/drc-health-data>) and map created by Freddy Bangelesa using ArcGIS 10.4, 2023

Table 1 Description of target study population, sampling techniques, and criteria judgment

| | Study design | Target population | Sampling size and technique | Criteria judgment |
|---|--------------------------|--|--|---|
| A | Household survey | Cross-sectional study Households with at least one child under the age of five | 432 households were selected through a three-stage clustered sampling technique [22], (the main objective of the study was to assess biomarkers) | - HFIAS - FCS - Food stocks |
| B | Market survey | Food census Official markets of Popokabaka Food items sold in the markets | Four official markets out of the six markets in Popokabaka (Cite Popo, Imbela, Ngasa, and Ibuka) were randomly selected, including 523 vendors All available food types were recorded. Weight and price were captured | - Food availability - Cost per 1000 g |
| C | Exit interview survey | Cross-sectional study Clients that were purchasing food at the local market | 147 clients were selected at the exit points of the four official markets of Popokabaka based on a systematic sampling with a sampling interval of 1 | - Food choices - Food affordability - Food accessibility - Client satisfaction |
| D | Focus group discussions | Qualitative case study Smallholder farmers affiliated with a cooperative farmers' organization possessing crops/livestock | Six FGDs were conducted, including a total of 48 participants purposively selected | Barriers to and opportunities for improved food production in Popokabaka |
| E | Key informant interviews | Qualitative case study Community leaders and civil society leaders involved in agricultural community organization | Seven key informants were purposively selected | Barriers to and opportunities for improved food production in Popokabaka |

urity Access Score (HFIAS), and Food Consumption Score (FCS).

- *The market survey:* In all four selected official markets, we recorded all foods being sold and interviewed all vendors present on the day of the visit. The food items' name, types of food group, quality, price, volatility, and seasonality were noted. Every food item was weighed using standardized kitchen scales to estimate the cost per 1000 g of net weight.
- *The exit interview:* Information on food choices, accessibility, and satisfaction was collected among 147 clients selected at the markets' exits.

Qualitative data

Qualitative data were gathered using a discussion or interview guide, respectively. Six focus group discussions (FGDs) and seven interviews with key informants (KIIs) were conducted in Lingala language. B.K.M. led all FGDs, and L.E. took notes. All discussions were recorded using a high-quality voice recorder after permission had been obtained from participants.

Data management and analysis

Quantitative data analysis

We reported the frequency and average cost per 1000 g of food within specific food groups. Food items that

recurred frequently were pinned and displayed graphically. For each household, three indicators were calculated: the Food Consumption Score (FCS), the Household Food Insecurity Access Score (HFIAS), and the Household Dietary Diversity Score (HDDS) [34]. The FCS classified households as having 'poor' (FCS \leq 28), 'borderline' (FCS between 29 and 41), and 'acceptable' (FCS \geq 42) consumption. The HFIAS classified households as food secure (HFIAS 1–5), mildly food insecure (HFIAS 6–10), moderately food insecure (HFIAS 11–15), and severely food insecure (HFIAS \geq 15). The HDDS was used to classify households as having diversified (HDDS $<$ 4) and non-diversified (HDDS \geq 4) diets. The analysis was performed in Stata 16.0.

Qualitative data analysis

All digital audio recordings were transcribed verbatim in French. Thematic analysis was used, as recommended by Braun and Clarke [35]. Data reduction and preparation were processed using Atlas.ti 22.0 software. In total, 13 transcripts were read and coded by B.K.M. and L.E. independently following two patterns (barriers and opportunities). After data reduction, 114 quotes were identified in the transcripts and clustered around 15 emergent sub-themes for barriers and 13 emergent sub-themes for opportunities. Sub-themes were then grouped into larger themes of barriers and opportunities. Quotations, codes,

and themes were listed in a Microsoft Excel matrix and translated into English at this stage. Finally, the themes were discussed with the remaining coauthors of this study to ensure conformability [36].

Integrating the results through a convergence integration framework

Both quantitative and qualitative information were linked and compared for convergence or divergence during the analysis and interpretation phases of the study using participative discussion techniques with all authors and experts in the food security field.

Results

Food security at the household level

The food security (food consumption and food access) measured at the household level was largely inadequate (see Table 2): the analysis of diet quality through the FCS revealed that only 18.6% of the 432 households visited had adequate food consumption. Moreover, food consumption was poor in 40.7% of the households and borderline in another 40.7% (see Table 2). When assessing households’ access to food, the HFIAS revealed a high prevalence of food insecurity in Popokabaka: only 1.6% of households were food secure, while 88.4% were severely food insecure.

Food stock mainly consisted of cassava roots, maize, and palm oil. Farming was the most common subsistence activity practiced in 92.1% of households, while livestock raising and fishing were practiced in 49.3% and 29.2% of households, respectively.

Food availability and cost at the market level

At the four official markets visited, 523 vendors were approached and interviewed. Their median

(Interquartile range) age was 32 (21) years, with four women for every man. Among the four markets, the Citepopo Market was the largest, with 232 (44.4%) vendors; it was followed by the Ibuka Market, with 138 vendors (26.4%). In total, 859 food items were recorded, listed, weighted, and evaluated for cost per 1000 g. Table 3 presents the distribution of food type availability across 13 food group categories. Green leaves, oleaginous products, condiments/spices, and manufactured foods were the most available and represented popular food groups sold at Popokabaka’s markets. Milk, meat, chicken, eggs, and pulses appeared rare at Popokabaka’s markets.

Table 3 Food availability in food groups censused across the four official markets in Popokabaka

| | Citepopo | Ngasa | Ibuka | Imbela | Total |
|-----------------------------|----------|-------|-------|--------|-------------|
| Cereals | 27 | 1 | 4 | 6 | 38 (4.4) |
| Tubers and roots | 34 | 12 | 20 | 16 | 82 (9.5) |
| Green leaves | 48 | 23 | 26 | 5 | 102 (11.9) |
| Fruits and other vegetables | 44 | 14 | 22 | 11 | 91 (10.6) |
| Oleaginous | 83 | 14 | 23 | 9 | 129 (15.0) |
| Pulses | 15 | 4 | 3 | 0 | 22 (2.6) |
| Meat | 7 | 5 | 2 | 0 | 14 (1.6) |
| Chicken/eggs | 1 | 1 | 5 | 3 | 10 (1.2) |
| Insects | 15 | 2 | 11 | 3 | 31 (3.6) |
| Fish and sea products | 30 | 5 | 6 | 5 | 46 (5.4) |
| Milk | 8 | 0 | 3 | 8 | 19 (2.2) |
| Condiments/spices | 110 | 15 | 15 | 21 | 161 (18.7) |
| Manufactured foods | 42 | 8 | 16 | 48 | 114 (13.3) |
| | 464 | 104 | 156 | 135 | 859 (100.0) |

Table 2 Food security at the household level determined by the Food Consumption Score (FCS) and the Household Food Insecurity Access Scale (HFIAS) in 432 Popokabaka households

| | N (432) | Proportion | CI95% |
|---|---------|------------|-----------|
| Food Consumption Score (FCS) | | | |
| Adequate | 80 | 18.6 | 15.1–22.4 |
| Borderline | 176 | 40.7 | 36.2–45.4 |
| Poor | 176 | 40.7 | 36.2–45.4 |
| Household Dietary Diversity Score (HDDS) | | | |
| Diversified | 133 | 30.8 | 26.6–35.3 |
| Non-diversified | 299 | 69.2 | 64.7–73.4 |
| Household Food Insecurity Access Scale (HFIAS) | | | |
| Food secure | 7 | 1.6 | 0.7–3.2 |
| Mildly food insecure | 9 | 2.1 | 1.0–3.8 |
| Moderately food insecure | 34 | 7.9 | 5.6–10.7 |
| Severely food insecure | 382 | 88.4 | 85.1–91.2 |

Figure 2 displays the most popular food item within each food group available at Popokabaka’s markets.

Regardless of the types of food, the most expensive foods were part of fish/sea products, meats, insects, chickens, and milk groups. Table 4 presents the mean food price in Congolese francs (with an estimation in US dollars) per 1000 g.

Food affordability and client satisfaction

A total of 331 clients were selected and interviewed as they were exiting the markets. Most of them were women (with a sex ratio of 3 to 1) with a median (IQR) age of 30 (18) years. In general, more than half of these

customers reported that foods were affordable to them. More than 70% testified that they purchased and brought back the food for which they came to the market. Table 5 reports the affordability and client satisfaction in the various markets combined, indicating higher availability than affordability.

Table 6 shows the distribution of food purchased by customers. The 1-day survey reveals that green leaves represented the food most often purchased overall in Popokabaka. However, there were variations depending on which market was under consideration. For example, fish and sea products represented the items most

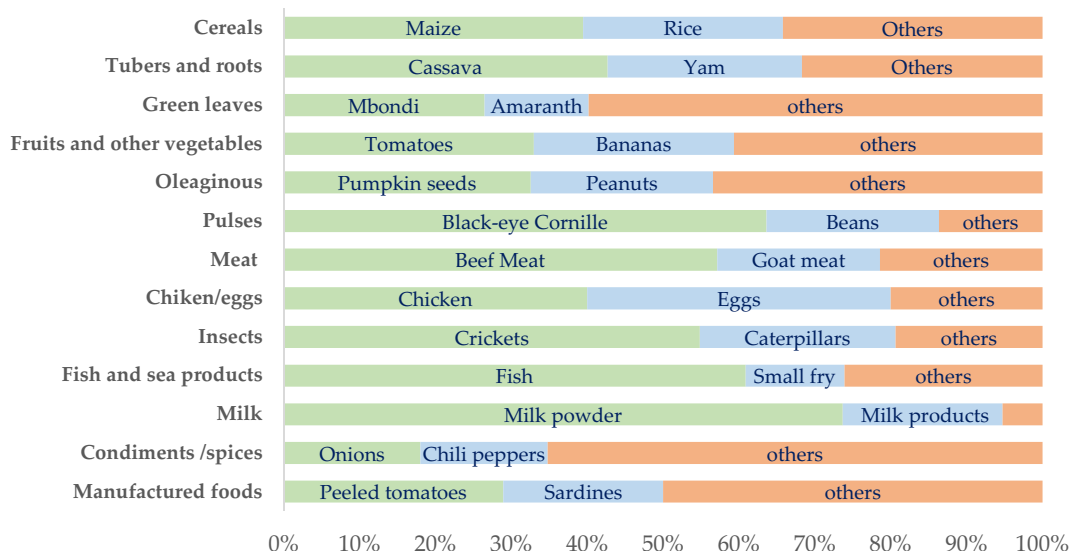


Fig. 2 Most frequent foods items in each food group found in Popokabaka markets

Table 4 Average cost (per 1000 g) of food items recorded at Popokabaka markets

| | Average cost with CI _{95%} in Congolese franc | Average cost + CI _{95%} in US dollars |
|-----------------------------|---|---|
| Fish and sea products | 76,502 (46,108–106,896) | 38 (23–53) |
| Meat | 59,744 (13,132–106,348) | 30 (7–53) |
| Insects | 41,156 (23,573–58,739) | 21 (12–29) |
| Milk | 30,920 (15,293–46,555) | 16 (8–23) |
| Chicken/eggs | 27,574 (9480–45,668) | 14 (5–23) |
| Condiments/spices | 26,444 (21,438–31,450) | 13 (11–16) |
| Manufactured foods | 18,915 (12,941–24,890) | 10 (6–12) |
| Green leaves | 12,679 (5881–19,477) | 6 (3–10) |
| Oleaginous | 10,118 (7964–12,273) | 5 (4–6) |
| Pulses | 8747 (5906–11,589) | 4 (3–6) |
| Fruits and other vegetables | 6919 (4791–9048) | 4 (2–5) |
| Cereals | 5927 (2289–9566) | 3 (1–5) |
| Tubers and roots | 2775 (1829–3722) | 1 (1–2) |

Table 5 Clients' perceived satisfaction about food availability and affordability when polled at the markets' exits

| | Are you satisfied with the food availability? | | Total (331) | |
|---------------------------------|---|-----------|-------------|------------|
| | No (108) | Yes (223) | | |
| Did you find what you came for? | No | 58 (53.7) | 27 (12.1) | 85 (25.7) |
| | Yes | 50 (46.3) | 196 (87.9) | 246 (74.3) |
| Are foods affordable for you? | No | 90 (83.3) | 18 (8.1) | 108 (32.6) |
| | Yes | 18 (16.7) | 205 (91.9) | 223 (67.4) |

Table 6 Distribution of affordability/choice of food items purchased by clients by food groups

| | Citepopo | Ngasa | Ibuka | Imbela | Total |
|-----------------------------|----------|-------|-------|--------|-------------|
| Cereals | 15 | 0 | 1 | 4 | 20 (4.5) |
| Tubers and roots | 13 | 3 | 3 | 6 | 25 (5.6) |
| Green leaves | 45 | 37 | 29 | 2 | 113 (25.3) |
| Fruits and other vegetables | 8 | 8 | 13 | 9 | 38 (8.5) |
| Oleaginous | 32 | 24 | 8 | 4 | 68 (15.2) |
| Legumes | 5 | 3 | 1 | 0 | 9 (2.0) |
| Meat | 6 | 8 | 2 | 0 | 16 (3.6) |
| Chicken/eggs | 0 | 0 | 1 | 0 | 1 (0.2) |
| Insects | 1 | 0 | 2 | 3 | 6 (1.3) |
| Fish and sea products | 58 | 11 | 12 | 4 | 85 (19.0) |
| Milk | 0 | 0 | 0 | 3 | 3 (0.7) |
| Condiments/spices | 21 | 24 | 1 | 1 | 47 (10.5) |
| Manufactured foods | 9 | 3 | 0 | 4 | 16 (3.6) |
| | 213 | 121 | 73 | 40 | 447 (100.0) |

often purchased at the Citepopo market, while more fruits were bought at the Imbela market.

Food production

Food production was assessed through a qualitative analysis of barriers and opportunities. Fifty-five individuals participated in focus group discussions and key informant interviews. Twenty-six of the participants were females and they had the following main activities: 21 farmers, eight fish farmers, 23 livestock producers, and three civil society and community leaders. Most of them identified themselves as being affiliated with community corporations. Data analysis identified key themes related to barriers and opportunities to food production in Popokabaka. Additional file 1: Appendix Table S1 presents themes, sub-themes, and a representative quote for each theme.

Barriers included a lack of adequate infrastructure for food production, a lack of motivation in food production activity, a lack of support and control systems, and rudimentary techniques. Overall, the community of Popokabaka relies more on plant cropping activities than livestock and fishing. Despite this, they mostly show a lack of motivation to improve crop production and rely on cassava, maize, and groundnut for home consumption:

"We have this will and courage to work and increase our production, but the problem is that we do not get profit from it. Merchants benefit from it a lot. When you sell your products at the merchants' price, you lose a slightly high percentage, 50% of the average revenue you would gain as a retailer. We understand that the road is bad, but this fact also discourages producing in large quantities."

Participants revealed challenges with livestock production, animal welfare, and lack of veterinarians and vaccines. In addition, it was rudimentary fishing activity, explaining the weak production of animal food sources.

"During the 1990s, there was the government's involvement in vaccination campaigns against livestock pests, and there were no tremendous losses compared to what we have now; however, the smallholders today are left to their own fate; they record enormous amounts of losses from their livestock. Although the dry season is known as the period in which livestock pests peak, in Popokabaka, we experience losses at any time of the year. Epidemics that were rare have become routine and permanent. All animals are concerned: pigs, goats, cows, and poultry. We suffer greatly, and this limited livestock provides an animal food source for the community. We truly need help."

Participants shared statements on Community acceptability, Foods locally produced, Food production activities, and Soil fertility stressing acceptance of items brought to them. They recognized that Popokabaka soil is fertile to any product implying that they will farm any nutritious imported crop with seeds, equipment, and technology provided to them. They also share a high acceptance and desire for new species and varieties introduction for crop and fish farming.

"Our soil accepts any crop. Because many of the crops that we use today have been imported, we have tried them, and the soil has responded well. For example, there were not any beans here; we brought them, and people tried them. Today, the soil is responding well. Apart from beans, we also

brought maize; people tried it, and maize gave them a good yield. There are a few households that use onions, which we brought; the yield grew, and the production was good. This means that the soil in Popocite is very fertile for everything we have brought, even in the old day. There were a few people who grew soybeans, and the yield was good, which means that if a crop is brought to us now, the production will be good because the soil we have is wealthy for everything."

Mixing quantitative and qualitative findings

We suggested three pathways to integrate household indicators with market measurements and farmers’ qualitative statements. They were:

1. *The poor diet quality pathway:* linking the high level of poor food consumption in households to low affordability of animal source food at a market level, grounded by a lack of adequate animal production systems and techniques.
2. *The culture-grounded dietary pathway:* linking the low dietary diversity in households to the high availability, at the marketplace, of green leafy foods and culturally grown crops plant, sustained by a lack of motivation to an improved and diversified Agriculture.
3. *The risk perception pathway:* contrasting the food access anxiety in households (expressed by the high level of severe food insecurity in households) with the unexpected satisfaction of buyers in a context of high community acceptability and commitment to their current situation

These pathways are detailed in Table 7.

Discussion and integration

In the present study, different methods and approaches were used to determine food security at different levels of the food chain by integrating information to design an effective action plan. We reported quantitative measures from household and market levels and linked them to qualitative themes we obtained from respondents about food production. Our main results suggested a higher level of poor food consumption, severe food access, and un-diversified dietary practices embedded in factors related to production, technologies, acceptability, affordability and culture. Foods varied at the market level, but animal-source foods were expensive and less affordable. Farmers’ statements argued for challenges and opportunities that could offer new ways of thinking. In the following paragraphs, we integrate this information into three pathways:

The poor diet quality pathway

Our analysis of food consumption revealed that 40.7% of Popokabaka’s households experienced poor food consumption FCS, an indicator used to characterize a community’s diet quality, is based on a 7-day food recall, in which the frequency with which foods from various food groups are consumed is weighted differently [37, 38]. Foods from animal sources (e.g., fish/meat and milk/dairy products) are weighted at the highest level, implying that communities that have an inadequate diet are characterized, for example, by a limited consumption of foods from animal sources, and show a high prevalence of poor food consumption as seen in the FCS indicator. When analyzing this pathway, we suspected that the poor quality of diets in Popokabaka would be linked to low consumption of foods from animal sources at the household level, which would explain the fair availability and high cost of these kinds of foods at Popokabaka’s local markets. Communities have limited healthier options at relatively higher prices. On the other hand, qualitative interviews indicated that farmers recognized that

Table 7 Food security pathways integrative picture in Popokabaka

| Quantitative findings | Qualitative findings | Integrative mixed pathways |
|---|--|---------------------------------|
| Household survey | Barriers | The poor diet quality |
| (A) FCS (40.7% of poor food consumption) | (1) lack of adequate infrastructure, | (A) ← (D) ← (3) (4) |
| (B) DD (69.2% of non-diversified diet) | (2) lack of motivation, | The culture-grounded dietary |
| (C) HFIAS (88.4% severely food insecure) | (3) lack of support and control systems, | (B) ← (E) (F) ← (1) (2) (6) (7) |
| Market survey | (4) rudimentary techniques | The Risk perception |
| (D) fair availability and high-cost animal-source foods | Opportunities | (C) ← (G) ← (5) (4) |
| (E) high availability of green leafy foods | (5) Community acceptability | |
| Exit interview | (6) Foods locally produced | |
| (F) affordability of green leafy foods | (7) Food production activities | |
| (G) client satisfaction with food purchased | (8) Soil fertility | |

The arrow ← means ‘may be explained by’

livestock and poultry were not developed because of illness. The literature has focused on the link between environmental availability, the accessibility of foods from animal sources, and poor diet quality at the household level. Baltenweck et al. [39] in 2020 reported that local livestock production increases the availability of foods from animal sources, which are better sources of the proteins and micronutrients that are necessary for a healthy population. Hetherington et al. [40] established relationships between livestock ownership, ASF consumption, and nutritional outcomes in children within the same households in rural villages in sub-Saharan Africa.

The culture-grounded dietary pathway

In contrast to the FCS indicator, which provides information about diet quality, the Household Dietary Diversity Score (HDDS) assesses a household's economic capability to access, afford, secure and consume more than four food groups. The score is based on 24 h food recall; when assessed repeatedly, this intake indicates dietary habits and culture. In the present study, diversity in diets was reported as being low (30.8%), meaning that two-thirds of the community did not have a diversified diet. This finding aligns with the availability of the most affordable foods at the market level, the low cost of leafy green vegetables, and the foods that are produced in the greatest quantities and most often mentioned, i.e., cassava, maize, and groundnuts. Previous research [25–27, 33, 41] conducted in the same area reported the prevalence of the traditional monotonous cassava diet and linked it to the prevalence of Konzo disease. We found that culture may influence food production choices, shaping food availability. Culture also influences dietary habits. Even if food is available, preferences, affordability and taboos can limit a household from adopting a diverse diet.

The risk perception pathway

The information generated by the HFIAS indicator is used to assess the prevalence of household food insecurity (based on the access component) and compare changes over time [42]. In contrast to the FCS and HDDS, that indicator is based on 30-day food recall and includes nine questions about the respondents' perceptions of food vulnerability or anxiety and their behavioral responses to that insecurity. Based on this indicator, 88.9% of households were classified as severely food insecure. This result implies that a considerable proportion of households include people who are anxious and uncertain about their respective households' food supply, the insufficient quality of the food they have access to, and their insufficient food intake. This perception of risk did not converge with nor diverge from the results of the qualitative inquiry about client satisfaction in food

purchasing and community acceptability. It was found that people did not stock up on food at the household level; indeed, they regularly got their food supply on each official market day. As they recall their food intake in the long term, they perceive the risk; however, as long as they could get enough food from what was available, they felt satisfied and developed a kind of positive defiance in the face of severe food insecurity. Some authors have described how the perceived risk of food insecurity and this high level of defiance are used to create local solutions.

Strengths and limitations

Food security is a complex and multifaceted concept, and needs multiple assessment methods to develop actions to address the issues within a community [15]. Mixed methods research is especially powerful to harness the strengths and counterbalance the weaknesses of both qualitative and quantitative approaches [29, 43]. This article complemented specific indicators and mixed information that explain the context of Popokabaka and suggest pathways of food insecurity that need to be addressed to achieve something at the household or individual levels. During this study, each component of the mixed method was assessed following rigorous methodologies to provide reliable findings. In our study the findings were largely convergent which supports trustworthiness of the qualitative findings. At the last stage of analysis, qualitative and quantitative data were integrated. This mixed approach was feasible and is suggestive of other settings. The interest of using such an approach assessment is recent [17] and continue increasing under food security sector [18, 19].

However, this mixed methods approach also has some limitations. First, the three pathways proposed are suggestive rather than exhaustive or absolute. However, based on our extended stay in the research region and our deep exploration and participatory approach, we suggest that these pathways are relevant to describe food security in the communities under study. Second, foods are highly linked to seasonality. The assessments we made at the market and within households should be repeated during the rainy season to compile an average situation. However, we expect that the food security situation described here is at its worst during the dry season and is probably better during the rainy season.

Conclusion

Regardless of the specific indicator used, the level of food insecurity in Popokabaka is alarming and requires effective actions to avert the most vulnerable individuals from experiencing negative nutritional and health

consequences. The present mixed-method analysis suggests that actions should focus on improving livestock development, developing an adapted communication strategy about nutrition to change engrained dietary habits and empowering the community for improved food security.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40066-023-00443-3>.

Additional file 1: Table S1. Themes and supporting quotes describing barriers and opportunities for food production.

Acknowledgements

The authors thank the participants and community members of Popokabaka for their collaboration and participation in this study.

Author contributions

BKM, MAM, IE and TS conceptualized the protocol of this research; BKM, EL, MAM and IE supervised fieldwork and data collection; BKM and EL performed data analysis; BMK prepared the original draft; all authors reviewed and contributed to editing the manuscript. Project administration: MAM, AH, and IE administered the project.

Funding

This research was funded by the Norwegian Agency for Development and Cooperation (NORAD), the Norwegian Higher Education (NORHED) Growing partnership for higher education and research in Nutrition (GrowNut Project: QZA-0484, COG-13/0002) in the Democratic Republic of Congo (DRC), and through the collaboration between the University of Kinshasa (DRC), the University of Kwazulu-Natal (South Africa), and the University of Bergen (Norway).

Availability of data and materials

Data sets, transcripts, and codes matrices served to this article are available as per request to the corresponding author.

Declarations

Ethics approval and consent to participate

The present study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Regional Committee for Medical and Health Research Ethics of Western Norway (ref: 2018/1420/R.E.K. vest, date: 30.11.2018) and the Kinshasa School of Public Health ethical committee (ref: ESP/CE/2019, date: 28.01. 2019). Other authorizations were requested from the local administrative and health authorities before any field work (households, markets, or food production places). Written informed consent was obtained from mothers or other caregivers for the household survey as well as from merchants and clients in the market survey. For the qualitative study, oral informed consent was obtained from participants before starting any discussion. We also obtained permission prior to recording any discussion. Confidentiality was maintained both in data management and when quoting respondents.

Consent for publication

All authors have agreed to the published version of the manuscript.

Competing interests

The authors declare no competing interests.

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Received: 22 March 2023 Accepted: 21 September 2023

Published online: 23 November 2023

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