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IDENTIFYING NUTRIENT GAPS AND PRIORITY FOODS IN SENEGAL: ADEQUACY OF NATIONAL PRODUCTION

AKADEMIYA2063 Brief
Nutrient Smart Processing and Trade (**NSPT**)

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Léa Magne Domgho,* Julia Collins, John Ulimwengu,*** and Ousmane Badiane******

*Senior Associate Scientist, AKADEMIYA2063
**Senior Associate Scientist, AKADEMIYA2063
***Senior Research Fellow, International Food Policy Research Institute (IFPRI)
****Executive Chairperson, AKADEMIYA2063

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Identifying Nutrient Gaps and Priority Foods in Senegal: **Adequacy of National Production**

Introduction

Micronutrient deficiencies stemming from inadequate consumption of vitamins and minerals, also referred to as hidden hunger, are a major nutrition, public health, and development issue around the globe (Tulchinsky 2015; Bailey, West and Black 2015). Senegal has placed significant priority on nutrition programs and investments and has made significant progress in improving nutrition outcomes over the past two decades (Malabo Montpellier Panel 2017). However, notable challenges remain, including that of hidden hunger. Significant micronutrient deficiencies exist in both urban and rural areas, particularly for calcium, iron, riboflavin, and zinc.[1] Senegal's Strategic Multisectoral Nutrition Plan 2017–2021 (PSMN) (Government of Senegal, 2017) called for action to reduce deficiencies in a number of nutrients, including iron, folic acid, iodine, zinc, and Vitamin A.

Improving diets and addressing nutrient deficiencies requires detailed analysis of nutrient gaps in terms of production, market availability, and consumption in order to assess the scale of the challenges and identify potential avenues to increase the availability of and access to nutrients. The Nutrient Smart Processing and Trade (NSPT) project led by AKADEMIYA2063 in collaboration with Senegal's *Conseil National de Développement de la Nutrition* (CNDN) with funding from the United States Agency of International Development (USAID) seeks to identify priority interventions for addressing micronutrient deficiencies in Senegal.

Following Marivoet and Ulimwengu (2022), the NSPT project carries out analysis on three types of nutrient adequacy measures: Nutrient Production Adequacy (NPA), Nutrient Market Adequacy (NMA), and Nutrient Household Adequacy (NHA). NPA expresses the ratio of the total quantity of a nutrient produced in an area to the total requirements of its population. NMA compares the total quantities of nutrients consumed with total requirements, and NPA compares average household-level consumption with requirements. Thus, NPA provides an overview of the adequacy of production; NMA shows the adequacy of the availability of nutrients for consumption in markets, without regard to unequal distribution between households; and NHA shows the adequacy of consumption at the household level (see Annex 1 for more details).

Comparing patterns of NPA, NMA and NHA and examining differences in the three types of nutrient adequacies can provide insight on the possible areas of nutrient loss and potential ways to increase nutrient intake. For example, the supply of nutrients could be enhanced through production-related interventions including biofortification or adjustments to the choice of crops produced; industrial fortification of foods; or increased imports in nutrient-rich foods. In cases where nutrients are produced in sufficient quantifies but inadequacies remain at the market and household levels, efforts can be made to address nutrient losses along the food value chains and increase households' purchasing power and access to markets. This brief describes results from the estimation and mapping of nutrient production adequacy and nutrient market adequacy carried out under the NSPT project.[2]

Although countries can improve the availability of nutrients through trade and industrial fortification, domestic production remains the most sustainable option to national food security and nutrient consumption adequacy, particularly in developing countries (Geyik, Hadjikakou, and Bryan 2020; van Ittersum et al. 2016).

1 See AKADEMIYA2063, *Identifying Nutrient Gaps and Priority Foods in Senegal: Nutrient Household Adequacy*. AKADEMIYA2063 Policy Brief, September 2023.
2 For a detailed discussion of nutrient household adequacy, see AKADEMIYA2063, Identifying Nutrient Gaps and Priority Foods in Senegal. AKADEMIYA2063 Brief, September 2023.

Nutrient market adequacy in turn shows the quantities of nutrients that are actually accessed for consumption, and the differences between production and market adequacy can suggest the limit of affordability and scale of losses through post-harvest activities, trade, processing, and other means. The brief discusses NPA and NMA for calories, protein, and 11 micronutrients (calcium, iron, zinc, Vitamin A, Vitamin B6, Vitamin B12, Vitamin C, folate, niacin, thiamin, and riboflavin) and identifies the major crops and livestock and fishery products accounting for Senegal's production of each nutrient. Nutrient adequacies are then mapped at the department level to analyze the geographical distribution of nutrient production and availability.

Data sources for nutrient production and consumption

The nutrient production adequacy analysis is based on crop production data from the *Enquête Agricole Annuelle* carried out by the Directorate of Analysis, Forecasting and Agricultural Statistics (DAPSA) in 2017–2018 (EAA 2017/2018). The DAPSA data are complemented by data from FAOSTAT, the Ministry of Fisheries and Maritime Production (MPEM), the Ministry of Livestock and Animal Production (MEPA) on palm oil, fishery, and livestock production, and the Directorate of Water, Forests, Hunting and Soil Conservation (DEFCCS) on non-timber forest products, respectively. Production data for most crops and animal products are available at the national and subnational levels; however, information on the production of palm oil and most fruits is only available at the national level. The nutrient market adequacy and nutrient household adequacy analysis is based on household survey data collected in 2017–2018 as part of the Projet d'Appui aux Politiques Agricoles (PAPA) led by Senegal's Ministry of Agriculture and Rural Equipment, the International Food Policy Research Institute, and Michigan State University with funding from the USAID. Production volumes and volumes of food consumed were converted into nutrient equivalents using the Food Composition Table for Western Africa for 2019 developed by the Food and Agriculture Organization of the United Nations (Vincent et al., 2020). Nutrient adequacy levels were calculated based on the recommended intakes defined in WHO/FAO (2005) and take demographic makeup of the population and of households into account.

The nutrients examined are all important contributors to bodily function and health. Deficiencies in iron, folate, zinc, and Vitamin A are thought to be the most common micronutrient deficiencies globally and are associated with major public health issues across the world (Bailey, West and Black 2015). In Senegal, limited data exists both on the prevalence of micronutrient deficiencies and on associated health impacts. Iron deficiencies have been estimated at 36.9 percent for women, zinc deficiencies at 58 percent for women and 43 percent for children, and Vitamin A deficiencies at 1.9 percent for women and 17.7 percent for children (Government of Senegal, 2017). Iron deficiencies are a leading cause of anemia, which was estimated to affect 66 percent of children in Senegal in 2015 (Government of Senegal, 2017).

Nutrient production, access, and consumption adequacy

Table 1 and Figure 1 present nutrient production adequacy (NPA), nutrient market adequacy (NMA), and nutrient household adequacy (NHA) for kilocalories, protein, and 11 micronutrients. NPA compares the total production of micronutrients to required amounts at national level. NMA computes the total amount of micronutrients accessed or consumed nationally, and NHA measures the level of micronutrient consumption by the average household. NPA is over 100 percent for most nutrients, suggesting that, on average, sufficient levels of nutrients are produced in Senegal to adequately feed the entire population.

Adequacy levels of protein, folate, niacin and thiamin are particularly high at over 200 percent. Despite this general pattern, production falls short of national requirements for calcium and riboflavin.

A very different pattern emerges in terms of consumption adequacy at national and average household levels, with NMA and NHA values significantly lower than NPA for most of the nutrients. For iron, zinc, Vitamin B6, folate, niacin, and thiamin, NMA and NHA levels are less than half those of NPA. This suggests that significant shares of the nutrients produced in Senegal do not make their way to households' tables, potentially due to limited purchasing power, food exports, post-harvest crop losses, and other nutrient losses along the food value chain or during the cooking process. Exceptions to this pattern include calcium, with a low nutrient household adequacy level that is nonetheless slightly higher than production adequacy, and Vitamin B12, for which nutrient market adequacy is slightly higher than production adequacy. Higher levels of NMA than NPA suggest that Senegal may have increased supplies of this nutrient through trade with other countries.

NHA is lower than NMA for most nutrients, indicating that national-level nutrient consumption is not distributed evenly among households. The difference between NMA and NHA is largest for Vitamin A and Vitamin B12, suggesting that there are significant disparities in households' access to foods rich in these nutrients (which include palm and other vegetable oils, and fish and meat, respectively).

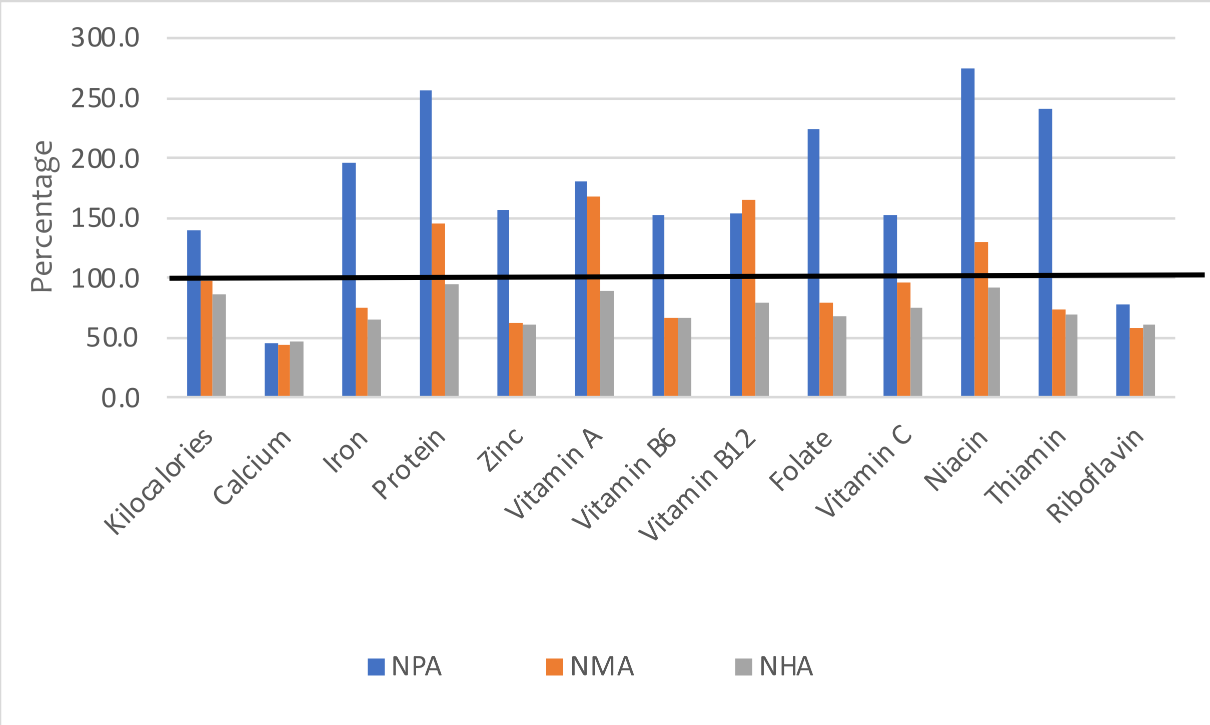
Table 1. National nutrient production, market, and household adequacy, Senegal (2017/18)

	Production per day, AME	Consumption per day, AME	Recommended intake per day, AME	Nutrient Production Adequacy (%)	Nutrient Market Adequacy (%)	Nutrient Household Adequacy (%)
Kilocalories (Kcal)	3855.8	2848.6	2750.0	140.2	97.3	86.5
Calcium (mg.)	449.0	485.0	1000.0	44.9	43.9	47.0
Iron (mg.)	53.6	21.1	27.4	195.8	74.5	65.0
Protein (g.)	128.5	78.1	50.0	257.1	145.2	94.3
Zinc (mg.)	21.9	9.2	14.0	156.8	62.0	60.9
Vitamin A (mcg.)	1084.8	1118.3	600.0	180.8	167.9	89.1
Vitamin B6 (mg.)	3.1	1.4	2.4	152.7	66.7	66.4
Vitamin B12 (mcg.)	3.7	4.5	400.0	153.6	165.2	80.0
Folate (mcg.)	897.7	331.8	60.0	224.4	79.0	68.3
Vitamin C (mg.)	91.4	64.7	20.0	152.4	96.0	75.6
Niacin (mg.)	54.9	27.7	1.5	274.6	129.4	91.5
Thiamin (mg.)	3.6	1.2	2.5	241.1	73.3	68.8
Riboflavin (mg.)	1.3	1.1	3.5	77.7	58.3	60.6

Source: Authors' calculations

Note: Consumption and market adequacy are based on PAPA data. Production adequacy is based on data from DAPSA, FAO, MEPA, MPEM, and DEFCCS.

Figure 1. Nutrient production adequacy, nutrient market adequacy, and nutrient household adequacy, Senegal (percent)

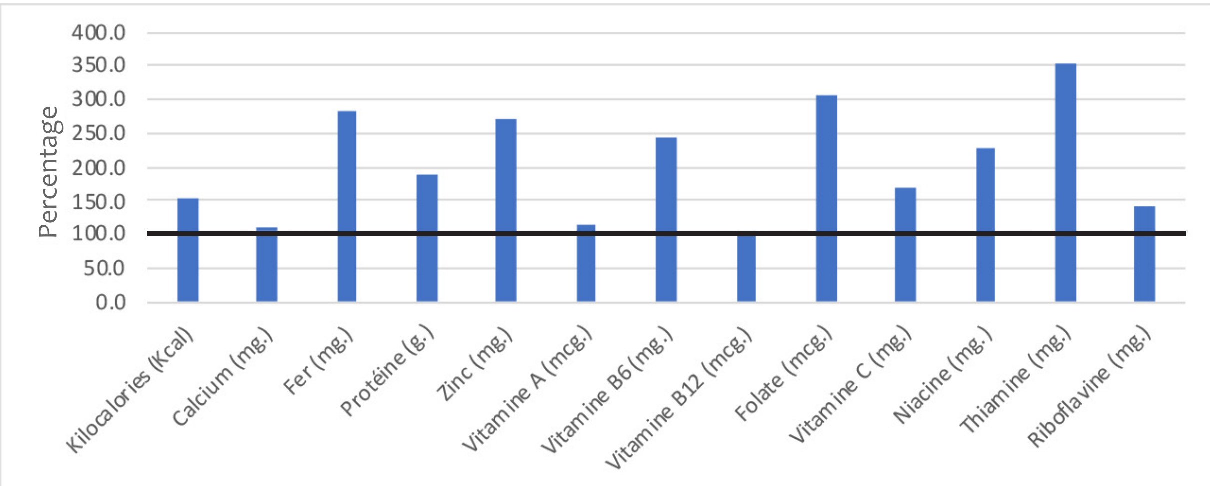


Source: Authors' calculations

Note: NPA = nutrient production adequacy; NMA = nutrient market adequacy; NHA = nutrient household adequacy. Consumption and market adequacy are based on PAPA data. Production adequacy is based on data from DAPSA, FAO, MEPA, MPEM, and DEFCCS.

Figure 2 shows the consumption coverage rate in Senegal, or the ratio of production to current consumption. For most micronutrients, production largely covers consumption. For iron, zinc, Vitamin B6, folate, niacin and thiamin, the country produces twice as much as needed to meet demand. On the other hand, the country produces just what is needed to meet the national demand for calcium, Vitamin B12, and Vitamin A, for which coverage rates are 109 percent, 100 percent and 116 percent respectively. This result, combined with those in Figure 1, is encouraging and shows that the country has the potential to provide adequate nutrients to its population and improve food and nutrition security.

Figure 2. Production/consumption coverage rate



Source: Authors' calculations

Note: Consumption and market adequacy are based on PAPA data. Production adequacy is based on data from DAPSA, FAO, MEPA, MPEM, and DEFCCS.

Table 2 summarizes the major crops accounting for Senegal's production of nutrients. It shows the dominant role of peanuts in national nutrient production: peanuts account for 20.0 percent of annual crop production in terms of volume and represent an even larger share of many major nutrients. Peanuts account for nearly 40 percent of all calories produced in Senegal and 60–70 percent of national production of thamin and niacin, as well as significant shares of protein, calcium, iron, zinc, Vitamin B6, folate, and riboflavin.[3]

Cereals—millet, rice, and maize—are also among the major sources of calories, protein, and most micronutrients. Millet, like peanuts, is among the top five sources of all nutrients except Vitamin A, Vitamin B12, and Vitamin C. Millet is rich in several key nutrients, representing 55.8 percent of national production of iron, 35.1 percent of folate production, and 28.4 percent of riboflavin production, compared to 12.5 of total crop production in terms of volume.

Cassava is the fifth largest source of calorie production and among the top sources of calcium, zinc, Vitamin A, and Vitamin C production. Animal products account for all of the top sources of Senegal's production of Vitamin B12 and also contribute to production of calcium, Vitamin B6, riboflavin, and niacin. Round sardinella fish accounts for 40.6 percent of Vitamin B12 production and is also among the top five sources of Vitamin B6 and niacin.

Calcium and riboflavin are among the few nutrients examined for which production is insufficient to cover national nutritional requirements. Peanuts account for the largest share of Senegal's production of calcium, followed by cow milk, while millet and peanuts account for the largest shares of riboflavin production. Increasing production of milk, which is relatively rich in both nutrients, would contribute to improving production adequacy levels; fortification would also offer an opportunity to further bolster the nutrient content of milk. Calcium production could also be increased by augmenting national production of sesame, which is extremely rich in calcium and currently represents only 0.2 percent of national crop production.

3 Peanuts play an important but less prominent role in nutrient consumption than in nutrient production. Peanuts are among the top five dietary sources of protein, folate, niacin, and thiamin, and peanut oil is a major source of Vitamin A (see Annex 2).

Table 2. The 5 main sources of nutrient production

Nutrient	Product	Share of nutrient production	Nutrient content 100gr	Share of prod.
Calorie	Peanut	36.6	574.0	20.0
	Millet	18.7	365.0	12.5
	Rice	16.0	347.5	14.5
	Maize	7.4	345.3	5.9
	Cassava	4.5	109.5	10.7
Protein	Peanut	42.9	22.4	20.0
	Millet	14.3	9.3	12.5
	Rice	9.5	6.9	14.5
	Maize	5.8	9.1	5.9
	Cowpea	4.9	23.1	1.5
Calcium	Peanut	24.6	45.0	20.0
	Cattle milk	12.3	191.0	
	Cassava	10.1	29.0	10.7
	Millet	10.1	23.0	12.5
	Sesame	5.0	777.0	0.2
Iron	Millet	55.8	15.2	12.5
	Peanut	16.0	3.5	20.0
	Rice	5.0	1.5	14.5
	Sorghum	4.7	5.2	3.1
	Maize	3.6	2.4	5.9
Zinc	Peanut	29.2	2.6	20.0
	Millet	23.2	2.6	12.5
	Rice	11.0	1.4	14.5
	Cassava	10.6	1.5	10.7
	Maize	5.8	1.5	5.9

Nutrient	Product	Share of nutrient production	Nutrient content 100gr	Share of prod.
Vitamin B6	Millet	22.6	0.4	12.5
	Peanut	18.5	0.2	20.0
	Rice	10.5	0.2	14.5
	Sardinella, round	7.7	1.3	
	Maize	6.7	0.3	5.9
Folate	Millet	35.1	160.0	12.5
	Peanut	30.1	110.0	20.0
	Cowpea	12.7	420.0	1.5
	Maize	5.1	55.7	5.9
	Sorghum	3.5	64.0	3.1
Vitamin C	Cassava	40.4	23.5	10.7
	Watermelon	10.6	6.0	16.8
	Onion	9.5	11.0	5.7
	Cabbage	9.5	54.0	1.1
	Tomato	9.2	28.0	2.1
Thiamin (Vitamin B1)	Peanut	59.2	0.9	20.0
	Millet	15.8	0.3	12.5
	Maize	5.9	0.3	5.9
	Rice	4.4	0.1	14.5
	Sorghum	3.1	0.2	3.1
Riboflavin (Vitamin B2)	Millet	28.4	0.2	12.5
	Peanut	26.1	0.1	20.0
	Watermelon	4.9	0.0	16.8
	Rice	4.7	0.0	14.5
	Cattle milk	4.4	0.2	

Vitamin A	Oil palm fruit	82.3	5310.0	1.8
	Mango	3.9	203.3	1.7
	Watermelon	3.7	25.0	16.8
	Cassava	2.9	20.0	
	Carrot	2.0	637.0	
Vitamin B12	Sardinella, round	40.6	8.3	
	Sardinella, flat	29.9	8.3	
	Sheep meat	6.7	3.0	
	Spanish mackerel	6.1	10.0	
	Beef	4.7	1.7	
Niacin (Vitamin B3)	Peanut	67.2	15.0	20.0
	Millet	7.2	2.0	12.5
	Rice	5.0	1.6	14.5
	Sardinella, round	3.0	9.1	
	Sorghum	2.9	3.3	3.1

Source: Authors using data from DAPSA (2017/18), FAO, MEPA, MPEM, and DEFCCS.

Note: Share of production refers to share in the volume of annual crop production in kilograms, not including livestock and fisheries.

Mapping of Nutrient Production Adequacy and Nutrient Household Adequacy

Figure 1 provides an overview of the geographical distribution by department of nutrient production and household adequacy levels for calories, protein, and the 12 micronutrients covered by this project. It should be noted that we used forest area at the departmental level to disaggregate national level data on palm oil and non-timber forest production.

Spatial patterns of the two adequacy measures differ markedly, with much lower levels of nutrient household adequacy than of nutrient production adequacy. For production adequacy, a similar geographical distribution appears for 8 (folate, thiamine, niacin, proteins, calories, Vitamin B6, zinc, and iron) of the 13 nutrients considered. For these nutrients, there is sufficient production across a good part of the national territory, although there are some areas of high concentration in the northwest, center, and southern parts of the country. The departments located in the valley of the Senegal River (Podor, Matam, Kanel and Bakel) and the Dakar region, as well as Thiès, Ziguinchor, Saint-Louis and Mbacké, tend to have a very low level of production adequacy. Indeed, these departments produce less than 70 percent of the recommended intake level per day and per adult male equivalent for many of the nutrients examined.

However, there are significant geographical differences in the coverage of requirements for different micronutrients. For example, the iron and zinc maps show higher levels of adequacy in areas where millet, which is particularly rich in these two nutrients (Table 2), is widely cultivated (the groundnut basin area, north of the Gambian border). For these two nutrients, there is a certain correlation between areas with high surplus of production and areas with larger quantities available in markets. However, the marketed quantities are below the quantities produced in most cases. This can be interpreted to result from food losses between production sites and markets, or from interdepartmental or cross-border trade. In terms of protein and niacin, most departments have a slight surplus of these nutrients on the markets, suggesting that markets are quite well supplied.

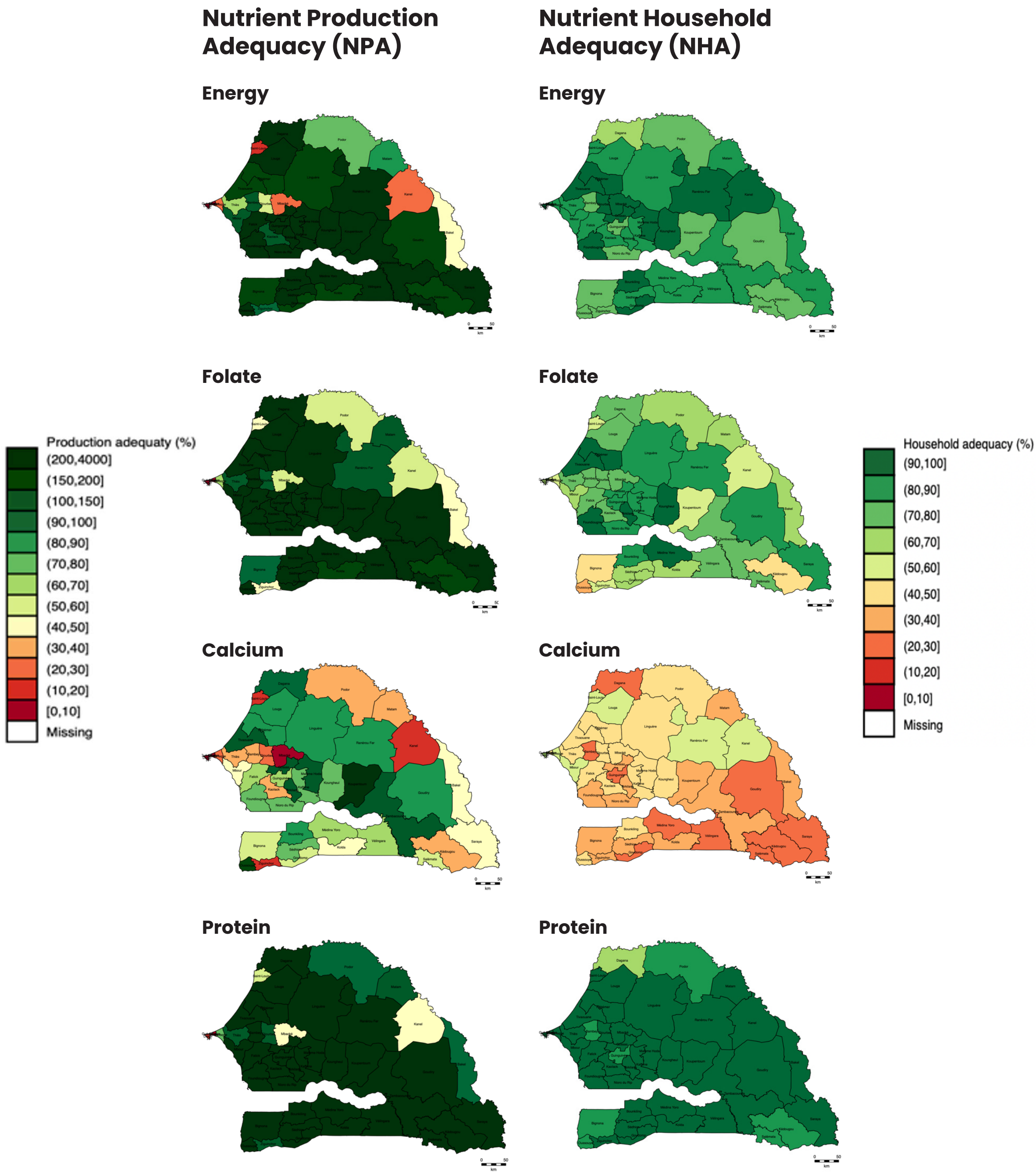
For Vitamin B12, production surpluses are observed in areas where livestock farming (or fishing) plays an important role in the economy (Rufisque, Mbour, Ranérou Ferlo, and Oussouye). However, in terms of consumption, it is possible that the large production surpluses of Vitamin B12 are mainly used to supply the west, southwest, and central parts of the country. In the south of the country, despite a fair level of production of Vitamin B12, the availability of this nutrient on its markets remains very low. This can result from sales outside the area and post-production losses due to transport, storage, etc.

Vitamin A is generally found in red and orange fruits and vegetables. Production surpluses are observed in the south of the country where oil palm is most concentrated. For household adequacy, the good performance of the Niayes area of coastal northwestern Senegal can be explained by horticulture production, and that of the Casamance area of southern Senegal by the production of palm oil for which this agroecological zone is well adapted. The departments of Goudiry, Saraya, and Kédégou, in spite of their production surplus, show the lowest levels of household nutrient adequacy in Vitamin A.

When considering the production and household adequacy of calcium, there is no doubt that the lack of domestic production of calcium-rich foods is a major concern. In fact, only the department of Koupentoum produces a large surplus of calcium. Market adequacy is low, especially in eastern Senegal where less than 30 percent of the recommended calcium level is available on the market. This could be explained by the crops present in this region (mainly cotton and some cereals) which are not very rich in calcium. Although not widely cultivated (0.2 percent of total crop production), sesame is a very good alternative to remedy calcium deficiencies, as it has a high calcium content (about 770 mcg per 100 g consumed).

The presence of livestock in the sylvo-pastoral zone, and millet in the groundnut basin area, could justify the excess riboflavin production observed in some of its departments. However, there is not always a correlation between areas of high production and consumption. For example, Oussouye and Koupentoum are among the best performing departments in terms of riboflavin production, but show some of the lowest levels of riboflavin consumption, with nutrient household adequacy levels under 50 percent.

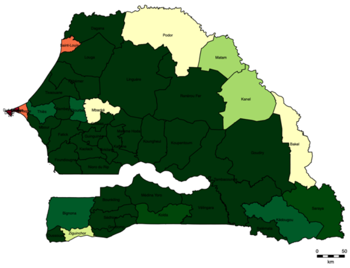
Figure 3. Mapping of nutrient production and household adequacy



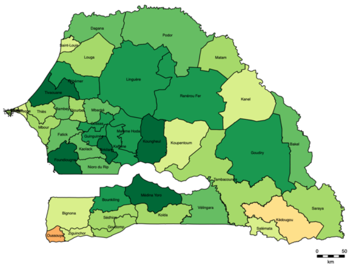
Nutrient Production Adequacy (NPA)

Nutrient Household Adequacy (NHA)

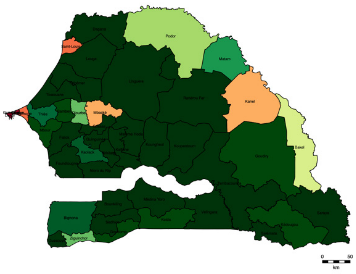
Iron



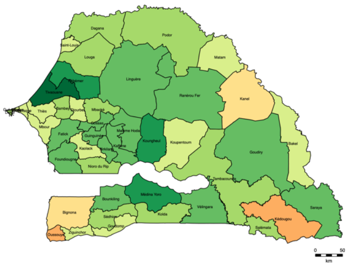
Iron



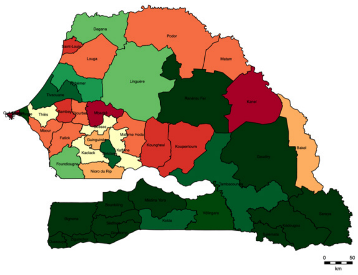
Zinc

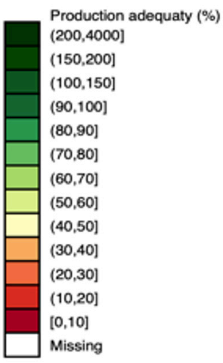


Zinc

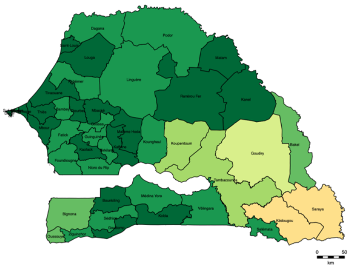


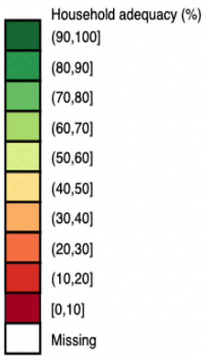
Vitamin A



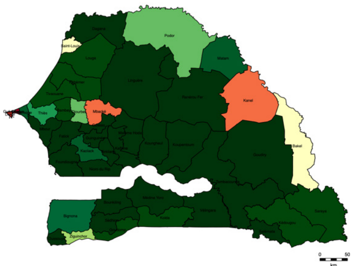


Vitamin A

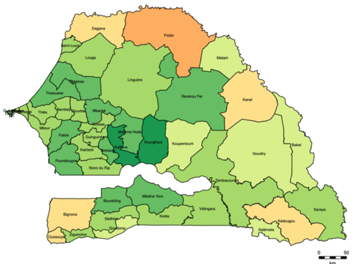




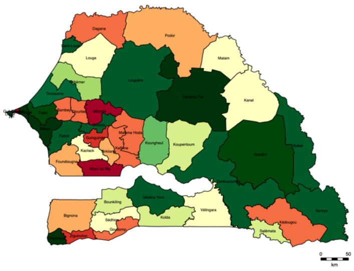
Vitamin B6



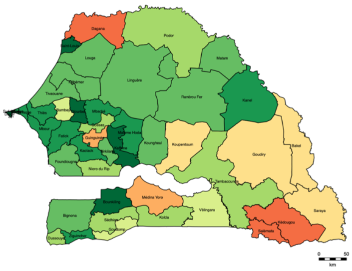
Vitamin B6



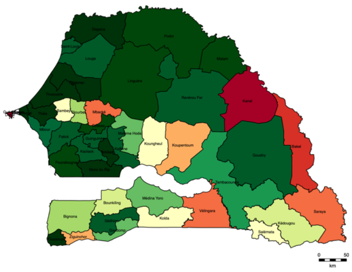
Vitamin B12



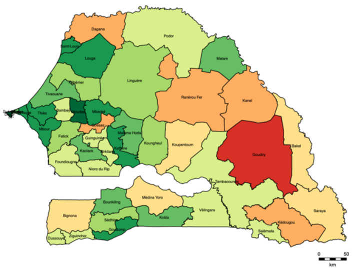
Vitamin B12

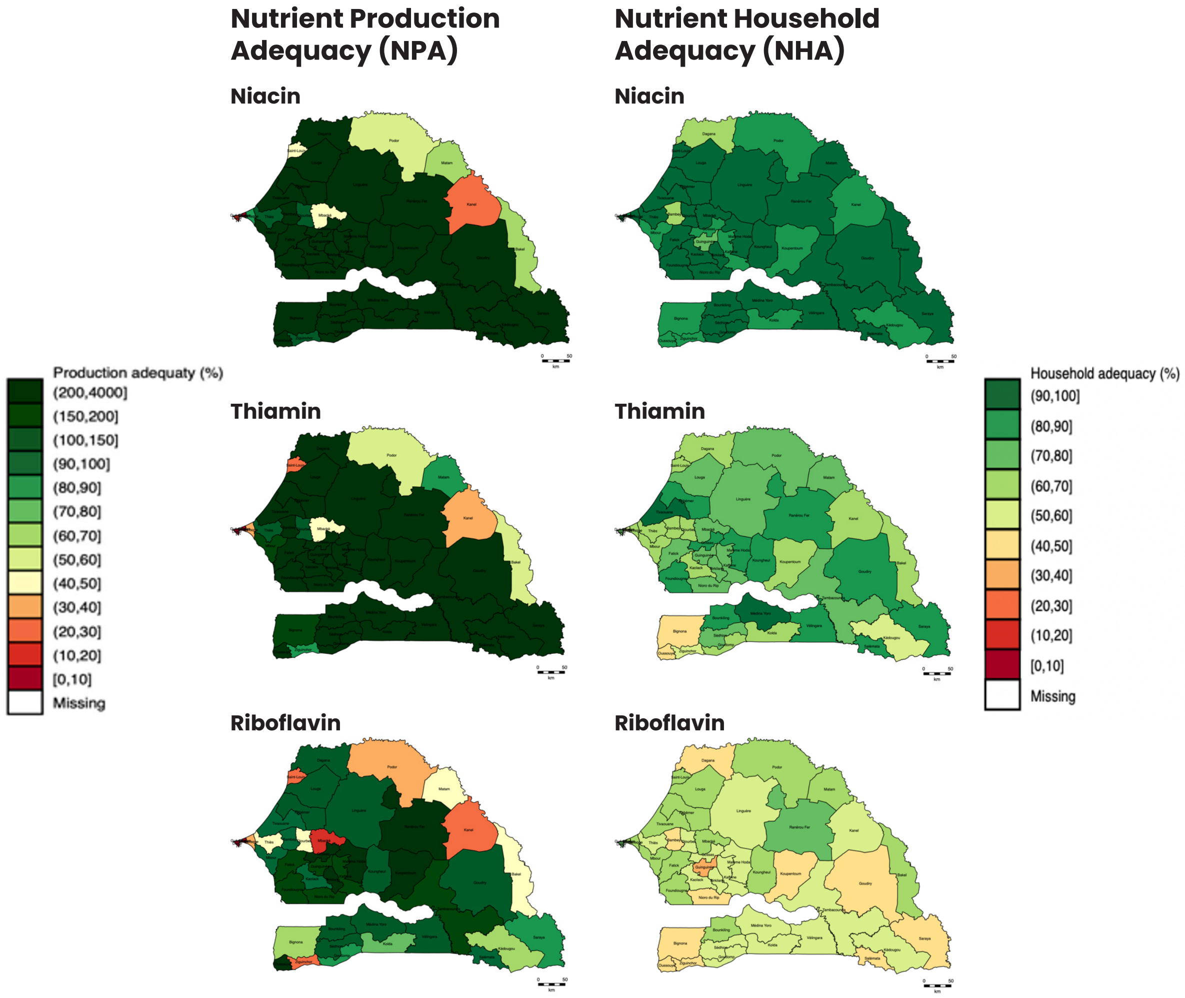


Vitamin C



Vitamin C





Source: Authors using data from DAPSA (2017/18), FAO, MEPA, MPEM, DEFCCS, and PAPA (2017).

Conclusion

This report uses maps and data on production adequacy, market supply and household consumption to identify and locate potential obstacles or difficulties that could explain the origin of micronutrient deficiencies in Senegal. Nutrient production adequacy assesses the balance between food production and the minimum energy and nutrient requirements of the population, while nutrient market adequacy provides an indication of the population's overall access to adequate amounts of calories and nutrients in a given locality.

For most micronutrients, the analysis reveals that Senegal produces more than the minimum requirement at household level. However, significant spatial heterogeneity is observed. The departments located in the northwest (except the regions of Dakar and Thiès), the center, and the south of the country generate a surplus of folate, thiamin, niacin, protein, calories, Vitamin B6, zinc, and iron, while those located in the Senegal River Valley (Podor, Matam, Kanel and Bakel), Dakar (region), Thiès, Ziguinchor, Saint-Louis and Mbacké suffer from insufficient food production (which varies between 0 and 90 percent). The comparative analysis of micronutrient production and market adequacy shows that areas with high production surpluses may be experiencing post-harvest losses or significant exports. On the other hand, areas suffering from insufficient food production could benefit from increased market integration.

The Dakar region is one of the areas that produces the least but shows very good availability of nutrients. This is not surprising, given that many products are directed to Dakar, which is not only the capital and largest city of the country, but also the Atlantic port.

The most problematic results are those of Vitamin B12, Vitamin A, and calcium. The low calcium market adequacy could be due to transport losses, as most of the fresh milk production infrastructure is located in the city instead of the countryside. Problems with the transport of raw milk could explain the low availability of calcium on the markets. Relocating industries that process raw production could constitute a strategy to improve availability.

Calcium production could be improved by increasing the production of milk, as it is an affordable source of calcium, and the production of sesame, which is extremely rich in calcium and represents only 0.2 percent of total crop production. As for Vitamin B12, fish has been found to be very rich in this nutrient. The heterogeneity of market integration may result from the perishable nature of certain foods.

The analysis of nutrient production adequacy, nutrient market adequacy and nutrient household adequacy together present a mixed picture of nutrient adequacy in Senegal. Despite sufficient production of most nutrients, the overall availability of nutrients for consumption in markets as well as household-level consumption are often below requirements. Results from nutrient adequacy analysis can be extended and used to inform the identification of opportunities to increase the availability of nutrients for Senegalese households. Future analyses should include an examination of cross-border trade patterns between Senegal and its neighbors to shed light on the flow of nutrients into and out of the country and guide strategies to increase the supply of nutrients through trade. Data on biophysical characteristics across the country4 can also be used to assess the potential for adjusting crop production patterns to increase community level supplies of key micronutrients with the largest intake gaps.

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4 Pixel-level data on biophysical conditions as well as crop production and yield predictions are available for Senegal and most other African countries on AKADEMIYA2063's Africa Agriculture Watch (AAgWa) platform: https://www.aagwa.org

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Annex 1. Analytical approach

The first component of the NSPT project, *identifying nutritional deficiencies and priority food products*, aims to quantify nutritional deficiencies and map the different types of nutritional adequacy. Following the model of Marivoet and Ulimwengu (2022) 2022, we apply the concept of nutritional adequacy to the pillars of food security: availability and access to food. Based on actual and recommended values for production and consumption, three types of adequacy measures will be calculated and mapped: Nutrient Production Adequacy (NPA), Nutrient Market Adequacy (NMA) and Nutritional Household Adequacy (NHA). The first type of map, Nutrient Production Adequacy (NPA map) shows the total amount of calories and nutrients produced by country ($Prod_{ij}$) divided by the recommended intake (RI_{ij}), using Adult Male Equivalence (AME) scales, depending on the demographic structure of the country. The NPA map therefore provides information on the degree of self-sufficiency of each country in terms of quantity and quality of the diet.

The second type of map, Nutrient Market Adequacy (NMA map), is based on the total amount of calories and nutrients consumed ($cons_{ij}$) in each country. The difference between the first two maps provides information on food losses within the country as well as opportunities for intraregional food trade. The third type of map, Nutritional Household Adequacy (NHA map), derives household energy and nutritional adequacy ($cons_{ij}/RI_{ij}$), before truncating all levels of adequacy above 1 (TR(.)) and averaging these truncated values by country[5]. The NHA map provides information on the distribution of food energy and nutrients among different households in the same country.

Various strategic issues related to food and nutrition security can be addressed using data provided by the NPA, NMA and NHA maps. These maps indicate, among other things, that when nutrient-deficient countries are properly informed, they can bridge the gap between their nutrient demand and supply by relying on their trading partners. Similarly, countries with excess nutrients can use their trading partners to expand their markets. The establishment of an effective trade partnership should strengthen the resilience of trading partners' food systems.

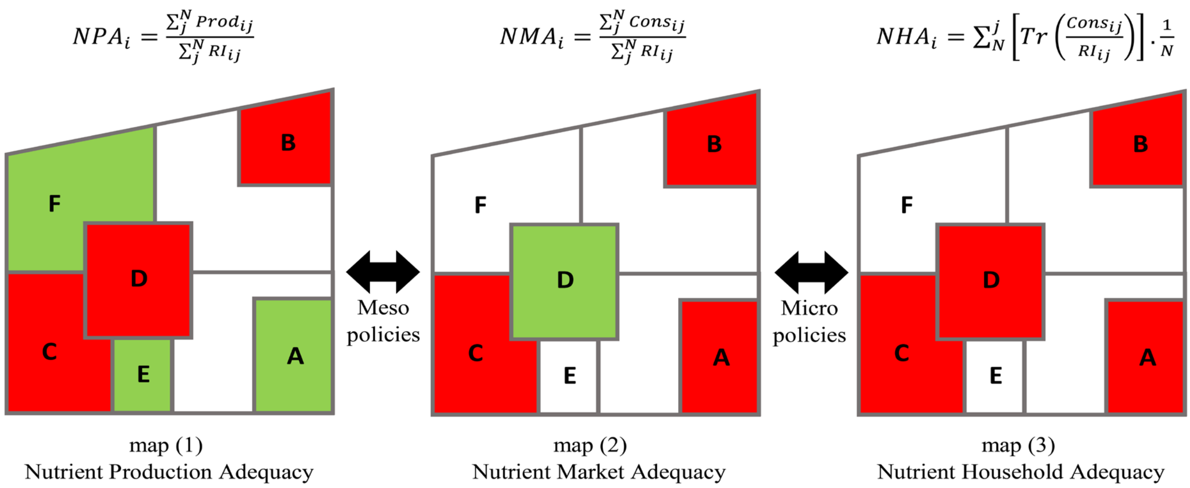
The NPA, NMA and NHA maps therefore provide a set of evidence-based decision-making tools for food security and trade. For illustration purposes, let us consider maps (1), (2) and (3) in Figure A1 for a hypothetical region where many households in countries A, B, C and D have insufficient intake in nutrient *i*. For example, the lack of nutrient intake in country A may result from post-harvest losses because the domestic production of this nutrient is more than sufficient. In country B, on the other hand, the best way to solve the same problem is to increase the production of food containing this particular nutrient, given its insufficient agricultural production combined with the absence of surpluses in neighboring countries. As regards country C, since the nutrient production of neighboring countries E and F exceeds the needs of their populations, increased trade with country C should be the appropriate response.

In country D, insufficient nutrient production was compensated, potentially by offers from countries E and/or F. However, despite this greater market integration, which has made it possible to obtain adequate nutrients at domestic market level, country D still suffers from nutrient deficiencies at household level.

5 The NHA measure fully aligns with the "nutritional adequacy ratio", which is the most commonly used term for this measure of diet quality (Ruel, 2002). The truncation function ensures that households with excess intake for a particular nutrient cannot compensate for the deficient intake observed in other households in the same country.

This means that despite the sufficient presence of nutrients in country D market thanks to regional trade, households' access remains below the recommended level. Real income levels may simply be too low among the poorest and among the most undernourished social groups in society. Therefore, policy responses at micro level should aim at strengthening their livelihoods, creating social protection programs to absorb shocks, or implementing other measures to ensure affordable prices for food products containing the missing nutrients. If affordability is not the problem, implementing awareness programs for more nutritious diets may be a more appropriate response.

Figure A1. Calculation and illustration of three types of measures of nutritional adequacy



Note: In the formulas, *I* represents the nutrient; *j* represents the household; *N* represents the number of households per region; *TR(.)* is a truncation function that sets all values greater than 100% to 100%. As a result of this latter function, the NHA index will always be between [0-100%], while the NPA index and the NMA index can be between [0-∞]. The color code applied is: white for values around 100% (= match) and red (green) for values significantly below (above) 100%, indicating a shortage (excess) situation.

Source: Marivoet and Ulimwengu (2018).

Measures of production, market and consumption nutrient adequacy will be estimated and mapped separately for each key micronutrient. The analysis will identify the absolute priorities in terms of interventions on the quantity and quality of the diet.

Annex 2. Main food products contributing to micronutrient intake, Senegal (national average)

	Food item	Nutrient intake share	Nutrient content 100gr	Budget share
Calories	Rice (broken)	18.7%	356.7	7.5%
	Rice (whole)	14.5%	352.3	5.8%
	Millet (processed)	7.9%	354.2	4.3%
	Vegetable oils	7.8%	900.0	4.9%
	Sugar	7.5%	400.0	4.8%
Protein	Rice (whole)	16.5%	10.8	5.8%
	Rice (broken)	16.4%	8.5	7.5%
	Fresh fish	7.9%	19.6	10.8%
	Peanut (processed)	6.6%	24.7	2.2%
	Millet (processed)	6.5%	7.9	4.3%

Calcium	Dried fish	17.7%	1939.0	1.2%
	Milk powder	15.5%	925.0	2.6%
	Rice (broken)	11.5%	35.4	7.5%
	Smoked fish	7.1%	1133.0	1.0%
	Rice (whole)	4.1%	16.3	5.8%
Iron	Millet (grains)	32.5%	15.2	2.5%
	Millet (processed)	16.3%	5.6	4.3%
	Rice (whole)	9.2%	1.7	5.8%
	Cowpea	4.9%	6.6	1.2%
	Maize (grains)	3.1%	3.3	1.2%
Zinc	Rice (whole)	15.6%	1.4	5.8%
	Millet (processed)	14.7%	2.3	4.3%
	Millet (grains)	11.9%	2.6	2.5%
	Cowpea	6.0%	3.8	1.2%
	Meat (beef, sheep, goat)	5.9%	3.1	7.1%
Vitamin A	Palm oil	35.8%	5720.0	1.3%
	Vegetable oils	19.4%	850.0	4.9%
	Peanut oil	11.5%	850.0	2.3%
	Carrot	10.0%	637.0	1.3%
	Other vegetable oils	5.6%	856.3	1.0%
Folate	Millet (grains)	21.7%	160.0	2.5%
	Cowpea	19.7%	420.0	1.2%
	Millet (processed)	8.4%	45.5	4.3%
	Peanut (processed)	6.6%	110.0	2.2%
	Rice (whole)	4.4%	13.0	5.8%
Vitamin B12	Dried fish	59.7%	60.0	1.2%
	Fresh fish	24.3%	3.3	10.8%
	Meat (beef, sheep, goat)	10.0%	2.2	7.1%
	Milk powder	3.3%	1.8	2.6%
	Poultry	1.5%	0.4	4.9%
Vitamin B6	Rice (whole)	13.7%	0.2	5.8%
	Millet (processed)	12.7%	0.3	4.3%
	Millet (grains)	10.6%	0.3	2.5%
	Fresh fish	7.6%	0.4	10.8%
	Maize (grains)	4.7%	0.3	1.2%
Vitamin C	Cabbage	15.4%	54.0	1.3%
	Mango	9.6%	35.0	1.6%
	Onion	8.2%	11.0	3.5%
	Fresh tomatoes	8.2%	28.0	1.4%
	Various leaves (bissap, parsley, green onion, etc.)	7.2%	67.6	1.4%
Thiamin (Vitamin B1)	Millet (grains)	11.6%	0.3	2.5%
	Millet (processed)	10.4%	0.2	4.3%
	Rice (whole)	10.3%	0.1	5.8%
	Peanut (shelled)	9.4%	0.9	1.0%
	Peanut (processed)	6.9%	0.4	2.2%

Riboflavin (Vitamin B2)	Rice (whole)	16.8%	0.1	5.8%
	Millet (processed)	11.6%	0.2	4.3%
	Rice (broken)	11.5%	0.1	7.5%
	Milk powder	8.9%	1.2	2.6%
	Millet (grains)	8.6%	0.2	2.5%
Niamin (Vitamin B3)	Rice (broken)	23.8%	4.3	7.5%
	Rice (whole)	18.0%	4.2	5.8%
	Peanut (processed)	9.8%	12.9	2.2%
	Peanut (shelled)	7.0%	15.0	1.0%
	Fresh fish	5.3%	4.6	10.8%

Source : Authors' calculations based on PAPA data.

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AKADEMIYA2063 - Kicukiro/Niboye KK 341 St 22 I 1855 Kigali-Rwanda | +250 788 318 315 / +221 338652881
kigali-contact@akademiya2063.org / dakar-contact@akademiya2063.org | www.akademiya2063.org
@AKADEMIYA2063