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Dietary diversity of women from soybean and non-soybean farming households in rural Zambia

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Introduction: Soybean farming in Zambia is promoted to increase farm productivity and diversification away from maize, and improve cash income and livelihoods for farmers. However, the impact of soybean farming on women's dietary intake is not clear. This study compares the dietary diversity of women from soybean (S) and non-soybean (NS) farming households as a pathway to understanding policy efficacy.

Methods: A cross-sectional survey involving 268 women of reproductive age from 401 rural households was conducted in two soybean-producing districts of Central Province, Zambia. Data from a qualitative 7-day food frequency questionnaire (FFQ) was used to calculate dietary diversity scores (DDS), women's dietary diversity scores (WDDS-10) and assess dietary patterns. Information on household sociodemographic and agricultural characteristics was used to explore determinants of dietary diversity.

Results: Results show there were no significant differences in the mean DDS (S: 10.3 ± 2.4; NS:10.3 ± 2.6) and WDDS-10 (S:6.27 ± 1.55; NS:6.27 ± 1.57) of women from soybean and non-soybean farming households. Both cohorts had similar dietary patterns, plant-based food groups with additional fats and oils. Agricultural diversity was not associated with dietary diversity. Household wealth status was the most important determinant of dietary diversity, as women from wealthier households were more likely to have higher DDS ($\beta = 0.262$, 95% CI = 0.26 to 0.70, $P < 0.001$) and WDDS-10 ($\beta = 0.222$, 95% CI = 0.08 to 0.37, $P < 0.003$) compared to those from poorer households. Women from households that spent more on food had a higher DDS ($\beta = 0.182$, 95% CI = 0.002 to 0.07), but not WDDS-10 ($\beta = 0.120$, 95% CI = −0.01 to 0.03); for every additional dollar spent on food in the past 7 days, the DDS increased by 0.18. Meanwhile, soyabean farming was not statistically associated with higher wealth.

Conclusions: Policymakers and promoters of agricultural diversification and nutrition-sensitive agriculture need to consider how women can benefit directly or indirectly from soybean farming or other interventions aimed at smallholder farmers.

KEYWORDS

soy, dietary diversity, Zambia, food system, women, farm production diversity, wealth status, nutrition-sensitive agriculture

1. Introduction

The United Nations Sustainable Development Goal Two (SDG2) has led to ambitious efforts to transform the food system into one that promotes sustainable development and meets the increased demand for food and nutrients from a rapidly growing population. Increasing policy prominence specifically points to efforts to end hunger, address food insecurity, improve nutrition, and promote sustainable agriculture by 2030 (Nkomoki et al., 2019; Atukunda et al., 2021). In response, national governments have promoted investments in agriculture around internationally linked value chains such as soybean, which are presented as great pathways through which farmers can benefit economically (Manda et al., 2019).

In the past two decades, Zambia has been under growing pressure to improve agricultural productivity to meet the food and nutrition needs of a rapidly growing population (FAO, 2017). This has highlighted the importance of agribusiness and foreign investments in value addition and processing (Mdee et al., 2020), underpinned by different smallholder coordination arrangements (Manda et al., 2018b). However, like other sub-Saharan Africa (SSA) countries, Zambia has a problem of limited agricultural diversity and productivity, with a dominance of maize (Mwanamwenge and Cook, 2019; Kapulu et al., 2020). Driven by increased multinational investment and policy support from the government, in the last two decades, soybean has increased contributions to the national-level supply of key dietary nutrients such as energy, protein, iron, zinc and calcium (Kapulu et al., 2022); however, the effect that soybean growing has on household-level diet quality is not well-understood. Historically, agricultural policies promoted maize production, neglecting crop diversification—only now are these emerging (Kapulu et al., 2022). Consequently, diets have predominantly remained poorly diversified, limiting the availability of macro and micronutrients (Joy et al., 2014; Kapulu et al., 2022), increasing the risk of dietary deficiencies and associated poor health outcomes (Afshin et al., 2019).

In Zambia, women and children are the most affected by undernutrition and micronutrient deficiencies (Doocy and Burnham, 2006; Zambia Statistics Agency, 2019), especially in rural areas (NFNC, 2014; Grech et al., 2018). Despite being important actors in the food system, population data shows that 30% and 14% of women were anemic and vitamin A deficient, respectively (Zambia Statistics Agency, 2019). Among children under 5 years of age, 58% were anemic, 35% stunted, 4% wasted and 12% underweight (Zambia Statistics Agency, 2019). Diversifying agriculture and other forms of nutrition-sensitive agricultural interventions, could be strategies that address nutritional deficiencies among rural households by increasing their access to a range of nutrient-dense foods such as fruits, vegetables, legumes, dairy and eggs (Jones et al., 2014; Mofya-Mukuka and Hichaambwa, 2018). A nationally representative survey in Malawi revealed a strong association between greater farm production diversity with increased consumption of legumes, vegetables and fruits (Jones et al., 2014). In the case of Zambia, the government and its stakeholders have promoted dietary diversity from the assumption that more diverse diets increase the likelihood of achieving caloric and micronutrient adequacy and improved nutritional outcomes (Sibhatu et al., 2022). The proposed pathways through which agriculture contributes to dietary diversity or diet quality include on-farm production and diversification, increased income from agriculture and higher expenditure on food. As an example, on-farm production diversification can be promoted through tax incentives for inputs required to grow healthier foods, improved access to farming advice, seeds and markets, and gendered agricultural empowerment (Ruel et al., 2018; Kaltenbrun et al., 2020; Sharma et al., 2021).

Zambia has developed policies toward agricultural expansion and sustainable intensification (Manda et al., 2019) and diversification of diets away from maize (Mwanamwenge and Harris, 2017). Using data from the 2015 Rural Agricultural Livelihoods Survey (RALS) longitudinal survey, Nkonde et al. (2021) explored household factors contributing to household dietary diversity scores in 7,934 households with children under 5 years in rural Zambia. The study showed that having male household heads, receiving extension advice on diversification, use of productivity enhancing inputs, practicing conservation tillage, education of mothers, amongst others, were significantly associated with households having a diversified diet and being more food secure (defined as having more than 6 months of adequate food provisions). However, the association between agricultural diversification and household dietary diversity score and adequate food provision were not statistically significant.

Soybean is a crop promoted among small-scale farmers to improve agricultural diversity and incomes. The increase is largely driven by expansions in the livestock and edible oil sectors, resulting in growing farmer participation in its production (Sitko et al., 2018). For instance, between 2006 and 2019, soybean production has increased from 57815MT to 281389MT representing a 320% increase (FAOSTAT, 2020). However, much emphasis has been placed on income from soybean production and biodiversity impacts (Manda et al., 2017; Sitko et al., 2018; Nuhu et al., 2021), as opposed to nutritional implications. Moreover, we did not find studies that explore the relationship between participation in soybean farming and nutrition outcomes in households with women of reproductive age.

The overall objective of this paper is to evaluate whether soybean farming contributes to dietary diversity of women in rural Zambia. The specific objectives were (i) to calculate and compare the dietary diversity of women from soybean and non-soybean farming households; (ii) to assess the dietary patterns in those households; and (iii) to determine what sociodemographic and agricultural factors are associated with dietary diversity.

2. Methods

2.1. Description of the study area

Zambia country has ten provinces and a population of 18 million (CSO et al., 2019). Nearly 1.5 million people live in the Central Province, and almost 75% of the households are in rural settings, from which 90% depend on agriculture for their livelihood. The province has a 56% poverty prevalence rate, while 54% of

FIGURE 1
District map of Zambia showing the main study areas Chibombo and Mkushi districts, respectively.

under-five children were in 2016 wasted, 11% are underweight, and 6% are stunted (CSO, 2016). Malnutrition severity levels range from medium to high (CSO, 2013, 2016). The province accounts for 43% of the area under soybean in Zambia, including 46% of the annual soybean production of 450 000MT (ZAMSTATS, 2020).

The study was conducted in two districts of the Central Province, specifically, Mkushi and Chibombo districts (Figure 1). Chibombo district is located south of Central Province near Lusaka and Kabwe—urbanized cities. The district has an estimated population of 294 000 and an annual growth rate of 2% (CSO et al., 2019). By contrast, Mkushi district is located further north of Central Province, away from major cities and has a population of about 149 000 with a 4% annual growth rate, the highest in the province (CSO et al., 2019). Both districts have a combination of subsistence and commercial farming settlements. However, 85% of farmers are smallscale (CSO, 2016). The few commercial farms occupy the more fertile lands near main trade routes with access to developed infrastructure (MAL-GRZ, 2016). These commercial farms cultivate maize seed, wheat and soybean (grain and seed). In contrast to large scale farming, smallscale agriculture occurs in more remote areas with less developed infrastructure and is characterized by poor soils (MAL-GRZ, 2016, 2018). Maize grain, groundnuts, and pulses such as common beans and cowpeas are grown for subsistence, with some households cultivating cash crops such as soybean, tobacco and cotton.

Marketing arrangements for smallscale agriculture in the two districts differ. In Mkushi, the farmers mainly depend on government-controlled markets, while Chibombo has a combination of government and other gateways to commodity markets in nearby urban towns (MAL-GRZ, 2016, 2018). Also, Chibombo hosts Mount Meru Limited, a multinational edible oil processing company that provides access to ready soybean markets and out-grower schemes for smallscale farmers located near the plant. Likewise, other multinational cotton ginneries located in Kabwe and Chibombo offer opportunities for cotton out-grower schemes to smallscale farmers (MAL-GRZ, 2018). In addition, Lusaka hosts well-established grain processing industries for livestock feed, food and edible oils that provide additional soybean markets for farmers in Chibombo (Samboko et al., 2018). Finally, compared to Mkushi, farmers in Chibombo have better access to agricultural advisory services, including government and NGO extension (MAL-GRZ, 2018).

2.2. Ethical considerations

Before undertaking the survey, ethical approval was obtained from ethics committees at the University of Leeds (Ref No. MEEC 18-009) and in Zambia by ERES (Ref No. 2019-Apr-008). In addition, the Zambian government granted clearance to conduct the household survey. During the survey, verbal consent was given by participants in the presence of a witness, normally a local leader, or a government official.

2.3. Data collection

Data collection was conducted over 10 days in May 2019. Five days were spent in each district. This period coincides with the primary harvest season for most crops such as soybean, maize, cassava and groundnuts. The interviews were conducted in three commonly spoken local languages: Bemba, Tonga, and Nyanja. At each household, an adult male or female (in most cases, the head of household) was the primary respondent. The dietary assessment considered responses from women only. Before data collection, questionnaire pre-testing involving 20 households was conducted in Chikumbi agricultural camp, Chibombo district, to ensure the questions were interpreted as intended before conducting the survey. Following the pre-test, the questionnaire was adjusted by rephrasing or including additional terms to some questions. Data were captured electronically on a tablet using a web-based open data kit (ODK) application. Interviews lasted between 50 and 90 min. The data was verified and uploaded to a server at the end of each interview.

2.4. Study sample

The sample comprised 401 respondents of which 268 women of childbearing age (15–49 years) completed the dietary assessment questions. The women were randomly selected using a multistage cluster selection process involving: (1) purposive selection of the two districts (Mkushi and Chibombo) based on soybean market linkages; (2) stratified random selection of four target agricultural camps[1] based on access to soybean markets; (3) selection of agricultural zones and determining the number of households for enumeration using probability proportional to size without

1 A camp is an official government geographical area delineated into zones for administrative purposes comprising agricultural households. The number of households per camp can range from 300 to 3000.

TABLE 1 The number of households and agricultural camps surveyed.

District	Camp	Number of zones sampled	Number of households surveyed
Chibombo	Kalola	3	100
	Nanswinsa	2	100
Mkushi	Ilume	3	100
	Nkolonga	2	100

replacing sampling; (4) simple random sampling of households for enumeration in each zone. As a result, 100 households were selected for enumeration from each respective camp in the two districts (Table 1).

Ten trained enumerators collected sociodemographic data, including household assets, family size, education status, market distance, and amount spent on food in the past seven days. Agricultural data included land ownership, size of agricultural land, ownership of livestock, and the number of crops cultivated in the past 12 months. Dietary data were collected using a list-based 7-day food frequency questionnaire (FFQ) without portion size estimation. The FFQ was adapted and modified from previous studies conducted in Ethiopia, Tanzania, and Zambia by including other foods commonly eaten in Zambia (WFP, 2008; Ambikapathi et al., 2019; Madzorera et al., 2021).

2.5. Study variables

2.5.1. Wealth status

An asset-based index was constructed using principal component analysis in the Statistical Package for Social Sciences (SPSS) to determine the wealth status of each household (Vyas and Kumaranayake, 2006; Rutstein, 2008). The following variables considered to be determinants of wealth included in the analysis were the type of material used for house walls and floors, primary lighting source, cooking energy source, type of roofing material, ownership of land, livestock, farm and household assets such as tractor, plows, TV, radio, mobile phones. These are reliable determinants of the household wealth status used to overcome bias challenges in self-reporting wealth by participants, especially in rural settings (Morris et al., 2000; Doocy and Burnham, 2006; Rutstein, 2008). All the variables were converted to binary format [yes (1) or no (0)] except for those already collected as continuous variables. The binary recoding indicated whether they were present or absent from a household.

Eigenvalues for each principal component indicated the percentage variation explained in the original data (Vyas and Kumaranayake, 2006). For example, the first component with a 26.4% variance explained in the original data was used to determine individual households' wealth status. Next, the wealth score values were added to the data as a variable for each household to create a new variable. Finally, this new variable indicating a wealth score was used to generate five quintiles representing a wealth index, ranging from 1 being the poorest to 5 the richest.

2.5.2. Farm production diversity score

The FPDS is a simple unweighted count of the number of food crops, plants and livestock species produced and kept on the farm (Sibhatu et al., 2015). The respondents were asked questions on the type of crops produced and livestock species raised on the farm in the last 12 months. The FPDS was calculated from a generated list of crop and livestock species categorized based on the FAO classification (FAO, 1994), including (1) cereals; (2) tubers; (3) pulses; (4) nuts and seeds; (5) vegetables; (6) fruits; (7) cattle; (8) poultry; (9) goats and sheep; (10) pigs; (11) rabbits and guinea pigs. Although farm productivity (total species count on-farm) is a determinant of wealth status (Jones et al., 2014), from a nutrition standpoint, it was necessary to group the species based on their nutritional contribution (Sibhatu and Qaim, 2018a). This approach was taken to avoid double-counting, especially crops (e.g., wheat and maize) with similar nutritional profiles and adding crop and animal species such as tobacco and donkeys, which are not consumed in Zambia. In the end, the FPDS was developed as a continuous variable ranging from 1 to 11.

2.5.3. Dietary diversity indicators

Dietary diversity is a valuable indicator of household and individual access to different foods and a proxy indicator of nutrient adequacy in the diet for individuals (Arimond et al., 2010; FAO FHI360, 2016; FAO, 2018).

A 7-day FFQ was used to collect information on habitual dietary intake. The dietary information was used to calculate dietary diversity score (DDS) and women's dietary diversity score (WDDS-10).

The DDS was calculated by adding the number of food groups reported consumed in the past 7-days based on 20 binary questions included in FFQ. These are based on an FAO classification of food groups commonly consumed in rural settings of low- and middle-income countries (FAO, 2018). The food groups were predefined as (1) cereals; (2) roots and tubers; (3) pulses; (4) nuts and seeds; (5) dark green vegetables; (6) vitamin A-rich vegetables; (7) other vegetables; (8) vitamin A-rich fruits; (9) other fruits; (10) red palm oil; (11) dairy; (12) meat and poultry; (13) organ meat (i.e., liver, heart, intestines or kidney); (14) eggs; (15) fish and seafood; (16) oils and fats; (17) savory and fried snacks; (18) sweets, confectionery and sweetened beverages; (19) condiments; (20) other beverages (e.g., tea, coffee and alcohol). A score of 1 (if consumed) or 0 (if not consumed) was assigned, to give a maximum score of 20.

The WDDS-10 was calculated using the 7 days binary FFQ data using 10 food groups. The 10 food groups (FAO FHI360, 2016) were aggregated from the list of 20 predefined lists described above and included the following: (1) cereals, roots and tubers; (2) pulses; (3) nuts and seeds; (4) dark green vegetables; (5) vitamin A-rich fruits and vegetables; (6) other vegetables; (7) other fruits; (8) dairy; (9)meat, poultry and fish; (10) eggs. A score of 1 (if consumed) or 0 (if not consumed) was assigned (FAO, 2018). Women who reported consuming at least five or more different food groups in the previous 7 days were expected to have a higher likelihood of achieving micronutrient adequacy compared to those who consumed food from fewer than five food groups (FAO FHI360, 2016; FAO, 2018).

Minimum dietary diversity (MDD-W) for women of reproductive age (MDD-W) is a dichotomous indicator used to establish the prevalence of women in a given population who achieve minimum dietary diversity (FAO FHI360, 2016) in this case among soybean and non-soybean farmers. The MDD-W is determined from 10 food groups used to estimate WDDS-10 and has a cut-off point of 5 (FAO, 2018). A value of 1 was assigned when a woman consumed at least 5 different food groups in the previous 7 days and 0 when otherwise.

2.6. Data analysis

Statistical Package for Social Sciences (SPSS) version 25 was used for all statistical analyses (Field, 2009). The normality of the data was checked using the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively. The variables representing the household, farming, women, and dietary characteristics were summarized as mean standard deviation (SD) or standard error (SE) were appropriate. Summary statistics were used to assess the composition of diets for soybean and non-soybean farmers. Analysis of variance (ANOVA) with Brown-Forsythe robust test was used to test the hypotheses that growing soybean increases mean DDS and WDDS-10, respectively. Bivariate analysis (at $P<0.05$ significance level) was conducted to explore for covariates under household (i.e., sociodemographic) and farming (i.e., agricultural) characteristics. In addition, variables were identified as potential confounders based on literature. This included district, farming system, women's education, women's age, gender of household head, education of household head, and age of household head.

A stepwise ordinary least square (OLS) multivariate regression model that included wealth status, household size, nearest market distance, and amount spent on food as explanatory variables and DDS and WDDS-10 as continuous variable outcomes to assess whether sociodemographic factors were predictors of women's dietary diversity. In addition, the model was adjusted for the district, farming system, women's education, women's age, gender of household head, education of household head, and age of household head. Further, a second model assessed the association between agricultural factors, including FPDS and women's dietary diversity. The OLS multivariate regression model included FPDS, the crop area cultivated under soybean, the proportion of crops grown consumed, and the proportion of crops harvested sold as explanatory variables with DDS and WDDS-10 as outcomes. The model was adjusted for confounder as above alongside wealth status. The model outputs included β-coefficients, 95% confidence intervals (CIs), and *P*-value for each explanatory variable.

3. Results

3.1. Characteristics of the study participants

The characteristics of study participants from the two farming systems [soybean (S) and non-soybean (NS) farmers] and at the district level (Chibombo and Mkushi) for soybean farming households only are shown in Table 2.

3.1.1. Household characteristics

More than 80% of the head of households in the farming systems were male. The average family size was six people per household. The level of education among household heads was moderately low, with many (61%) having attended school only up to the primary level. Chibombo had a higher proportion (44.2%) of households ranked as "poorest and poor" than the 35.7% from Mkushi. The primary source of income was from on-farm activities, comprising mainly crop production with some livestock keeping.

3.1.2. Farming characteristics

Households in the survey had access to an average of 5.0 ha of land, while an average of 3.1 ha was used for agriculture in the preceding 12 months. More than 80% owned the land. The mean (±SD) number of crops grown was 3.0 ± 0.15 and 2.1 ± 0.08 for the two farming systems. A further look at the soybean farmers at district levels showed that the mean (±SD) number of crops grown were 3.0 ± 0.16 in Chibombo and 3.1 ± 0.19 in Mkushi. Maize, soybean, beans, sweet potatoes and tomatoes were the most common crops grown. Many households owned livestock, especially chickens and goats, with a few having cattle and pigs. The mean (±SD) FPDS was statistically significantly different for the two farming systems 5.4 ± 0.26 and 3.6 ± 0.13 ($P < 0.001$) for soybean and non-soybean farms, respectively, and for districts, 4.3 ± 0.25 and 5.9 ± 0.25 ($P < 0.001$) Mkushi and Chibombo, respectively.

3.1.3. Women's characteristics

The mean age for women was 33 years. About 50% of the women attended school up to the primary, but only 20% completed secondary and tertiary levels. More than 80% of the women were married.

3.2. Effect of soybean farming on dietary diversity indicators

3.2.1. Diet diversity score

The mean DDS for women from soybean and non-soybean farming households are shown in Table 3. Analysis of variance (ANOVA) with Brown-Forsythe robust test was used to determine if soybean growing affected mean DDS. The results show that the mean (±SD) DDS between soybean (10.3 ± 2.4) and non-soybean (10.3 ± 2.6) farmers did not differ significantly ($P = 0.909$). Further analysis of soybean farming households showed that the mean (±SD) DDS of women from Chibombo district (10.2 ± 2.3) did not differ significantly ($P = 0.629$) from those from Mkushi district (10.5 ± 2.8) (Table 3).

3.2.2. Women's diet diversity score based on 10 food groups

The WDDS-10 for women from soybean and non-soybean farming households are shown in Table 3. The results show that the mean (±SD) WDDS-10 of women from soybean (6.27 ± 1.55) and non-soybean (6.27 ± 1.57) farming households did

TABLE 2 Demographic, agricultural and dietary characteristics of the sampled households and women according to the farming system and district.

Characteristics	Farming system		District	
	Soybean households	Non-soybean households	Chibombo (soybean households)	Mkushi (soybean households)
Household characteristics (*n*)	110	291	73	37
Gender of household head (%)				
Male	84.5	81.4	87.7	78.4
Female	15.5	18.6	12.3	21.6
Average family size ± SD	6.9 ± 2.6	6.7 ± 2.5	7.0 ± 2.9	6.8 ± 2.4
Education level of household head (%)				
No formal education	1.8	4.8	27	0
Primary school incomplete	40.9	36.8	43.8	35.1
Primary school complete	20.0	23.7	19.2	21.6
Secondary school incomplete	24.6	21.3	24.7	24.3
Secondary school complete	11.8	10.3	9.6	16.2
Tertiary education	0.9	3.1	0	2.7
Wealth status (%)				
Poorest	15.5	21.6	19.2	8.1
Poorer	14.5	22.0	15.1	13.5
Middle	23.6	18.9	27.4	16.2
Richer	19.1	20.3	16.4	24.3
Richest	27.3	17.2	21.9	37.8
Mean number of income sources ± SD	1.9 ± 1.1	1.7 ± 0.9	1.8 ± 0.1	1.8 ± 0.1
Farming characteristics				
Mean total accessible land (ha) ± SE	6.1 ± 0.9	4.1 ± 0.6	6.4 ± 0.7	9.8 ± 3.3
Mean total agricultural land (ha) ± SE	3.8 ± 0.4	2.6 ± 0.3	5.0 ± 0.5	3.2 ± 0.6
Own land (%)	93.6	86.3	94.5	91.9
Own livestock (%)	91.8	77.7	98.6	78.4
Mean number of crops grown ± SE	3.0 ± 0.2	2.1 ± 0.1	3.0 ± 0.2	3.1 ± 0.2
Mean number of livestock species kept ± SE	2.4 ± 0.2	1.5 ± 0.1	2.9 ± 0.2	1.2 ± 0.2
Mean number of food crops grown ± SE	2.8 ± 0.2	2.0 ± 0.1	2.7 ± 0.1	3.1 ± 0.2
Mean farm production diversity score (FPDS) ± SE	5.4 ± 0.3	3.6 ± 0.1	5.9 ± 0.3	4.3 ± 0.3
Women's characteristics (*n*)	66	202	45	22
Mean age (years) ± SD	32.8 ± 9.8	33.7 ± 10.1	33.6 ± 1.7	33.2 ± 1.8
Education level (%)				
No formal education	6.3	5.6	4.4	9.1
Primary school incomplete	42.9	51.0	46.7	36.4
Primary school complete	17.5	20.4	17.8	22.7
Secondary school incomplete	22.2	18.4	20.0	9.1
Secondary school complete	11.1	4.6	11.1	7.0
Dietary characteristics				
Mean dietary diversity score (DDS) ± SD	10.3 ± 2.4	10.3 ± 2.6	10.2 ± 2.3	10.5 ± 2.8
Mean women's dietary diversity score (WDDS-10) ± SD	6.3 ± 1.6	6.3 ± 1.6	6.2 ± 1.7	6.4 ± 1.3
Mean amount spent on food last 7 days $USD ± SD	9.7 ± 0.8	9.4 ± 0.5	8.1 ± 1.0	12.9 ± 1.6

TABLE 3 Mean ±SD dietary diversity scores (DDS) and women's dietary diversity scores (WDDS-10) categorized according to the farming system and district.

Indicator	Farming system				District			
	Soybean	Non-soybean	*N*	*p*-value	Chibombo (soybean only)	Mkushi (soybean only)	*N*	*p*-value
DDS ± SD	10.27 ± 2.41	10.23 ± 2.59	268	0.909	10.16 ± 2.26	10.47 ± 2.76	66	0.629
WDDS-−10 ± SD	6.27 ± 1.56	6.27 ± 1.57	268	0.981	6.21 ± 1.70	6.39 ± 1.30	66	0.636

The results of ANOVA with the Brown-Forsythe robust test are shown at a 95% significance level.

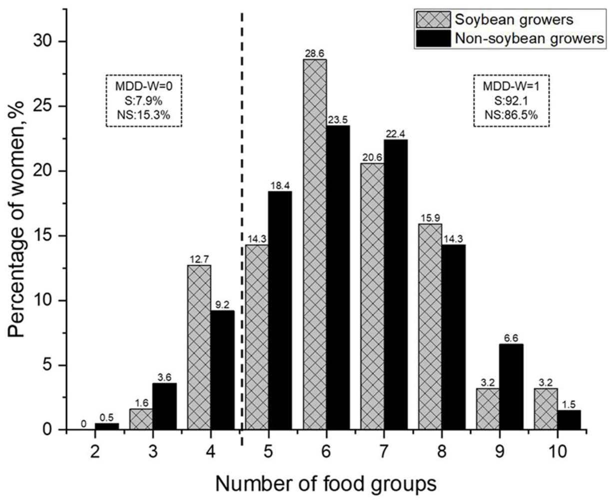

FIGURE 2
Percentage of women achieving different women's dietary diversity scores (WDDS-10) and prevalence of the minimum dietary diversity for women of reproductive age (MDD-W) among soybean (S) and non-soybean farmers (NS). MDD-W = 1 if the women consumed at least five or more different food groups during the past seven days and 0 otherwise. The dotted line denotes a cut-off point for MDD-W. $N = 268$.

not differ significantly ($P = 0.981$). Further analysis of soybean growing households district showed that the mean (±SD) WDDS-10 of women from Chibombo district (6.2 ± 1.7) did not differ significantly (P = 0.636) with those from Mkushi district (6.4 ± 1.3) (Table 3).

3.2.3. Minimum dietary diversity

The WDDS-10 calculated from food groups consumed in the previous seven days and the proportion of women who achieved the minimum dietary diversity (MDD-W) were further investigated (Figure 2). More than 86% of women from soybean and non-soybean households achieved the MDD-W (i.e., WDDS-10 $\geq$ 5), while 14% of women did not achieve MDD-W (i.e., WDDS-10 $<$ 5). In this case, the diet comprised of plant-based foods primarily. For example, those who consumed two food groups tended to eat cereals and dark green vegetables. Those who consumed three food groups consumed starchy roots in addition to cereals and dark green vegetables. Only a few reported eating eggs (13%) and fish (38%). As the WDDS-10 increased, the diets comprised mostly starchy roots, dark green vegetables, and other vegetables with other food groups such as pulses, eggs, fish, dairy, organ meat, and meat. Likewise, when the district is considered, over 86 women from soybean farming households in Chibombo and Mkushi achieved an MDD score of 1, consuming >5 food groups daily (Supplementary Figure 1).

3.3. Composition of the diets

Figure 3 shows the percentage of households from which women reported consuming a food group in the past seven days. The results confirm the observations with WDDS-10 of a general dominance of plant-based food groups in the diets. Cereals are consumed by more than 95% of households. Nearly 90% reported consuming dark green vegetables and other vegetables, while pulses, roots and tubers, and nuts and seeds were consumed by over 60% of the households. About 50% of the households reported consuming animal products such as fish, eggs, meat, and poultry in the past seven days. A few households reported consuming other food groups such as fruits, dairy, and vitamin A-rich foods. Notably, 20.9% of women from non-soybean farming households said they consumed snacks in the past seven days compared to 77.8% from soybean farming households, while 50.5% from non-soybean farming households consumed sugary foods against 43.1% soybean farming households. Likewise, 86.7% non-soybean farming households said they consumed condiments in the past 7 days compared to 77.8% from soybean farming households.

Further analysis of dietary patterns among women from soybean-farming households in the two districts revealed that women ate mostly similar foods (Supplementary Figure 2). More than 90% of the women from both districts reported consuming cereals, dark green vegetables, and other vegetables. Notably, the consumption of vitamin A rich fruits, other fruits, dairy, and vitamin A rich vegetables ranged from 6 to 35% in the two districts. However, over 80% reported consuming roots and tubers in Mkushi compared to 65% from Chibombo. Likewise, 80% consumed pulses in Mkushi against 50% in Chibombo, and 84% of the women in Mkushi ate fish compared to 50% from Chibombo. A possible explanation to this is that Mkushi compared to Chibombo has several rivers and streams. In contrast, nuts and seeds were consumed more in Chibombo (91%) than Mkushi (50%). Organ meat (15.0 vs. 3.8%), including meat and poultry (65.2 vs. 34.6%), were also reported to have been eaten more by women from Chibombo than Mkushi, respectively. On the other hand, oils and

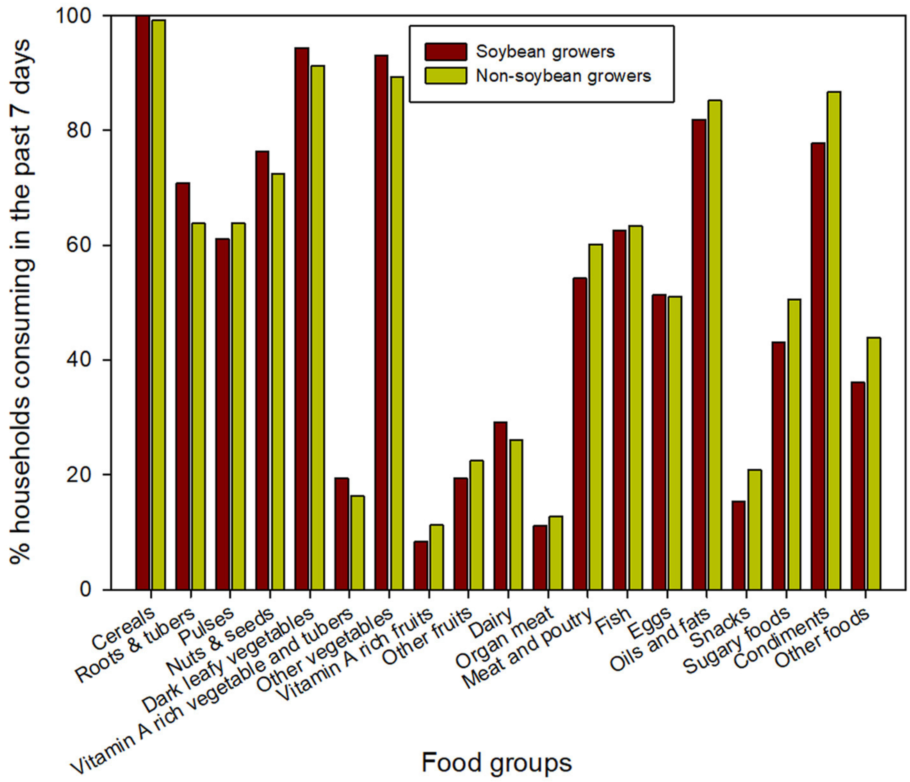

FIGURE 3
Percentage of women from households who reported consuming a food group in the past 7 days.

TABLE 4 Multivariate regression analysis of the relationship between dietary diversity scores (DDS) and women's dietary diversity scores (WDDS-10) and agricultural factors.

Variable	DDS				WDDS-10			
	Adjusted[a] β	95% CI		*p*-value	Adjusted[a] β	95% CI		*p*-value
Farm production diversity score unweighted	0.069	−0.255	0.196	0.334	0.090	−0.104	0.189	0.222
Proportion of crop area cultivated under soya	0.048	−1.582	3.913	0.647	0.061	−0.964	2.602	0.575
Proportion of crop harvested consumed	−0.011	−0.902	2.299	0.856	0.008	−0.809	1.269	0.903
Proportion of crop harvested sold	0.141	0.070	3.680	0.036	0.087	−0.626	1.717	0.214

Data are presented as β, 95% confidence intervals, p-value and were analyzed by multivariate regression analysis.
[a] Adjusted for district, farming system, women's education, wealth status, women's age, gender of household head, education of household head, and age of household head.

fats were equally eaten by 87% of the women in Chibombo against 73% from Mkushi.

3.4. Factors related with women's dietary diversity

3.4.1. Agricultural factors associated with women's dietary diversity

Table 4 shows the results of a multivariate regression analysis of the relationship between selected household agricultural characteristics with DDS and WDDS-10. The analysis was adjusted for district, farming system, women's education, women's age, gender of household head, education of household head, age of household head and wealth status (see Supplementary Table 3 for unadjusted model outputs). DDS and WDDS-10 were not statistically significantly associated with farming diversity indicator FPDS ($P = 0.334$; $P = 0.222$), proportion of crop area cultivated under soybean ($P = 0.647$; $P = 0.575$), and proportion of crops grown consumed ($P = 0.856$; $P = 0.903$). Notably, the regression analysis shows that the higher proportion of crop harvested sold was associated with greater DDS (β = 0.141, 95% CI = 0.70–3.60) but this was not the case with WDDS-10 (β = 0.087, 95% CI = −0.626 to 1.717). For every kilogram of crop harvested that was sold, DDS increased by 0.141.

TABLE 5 Multivariate regression analysis of the relationship between dietary diversity scores (DDS) and women's dietary diversity scores (WDDS-10) and sociodemographic factors.

Variable	DDS				WDDS-10			
	Adjusted[a] β	95% CI		p-value	Adjusted[a] β	95% CI		p-value
Wealth status	0.305	0.274	0.727	<0.001	0.230	0.080	0.373	<0.001
Household size	0.106	−0.101	0.150	0.102	0.125	−0.037	0.125	0.056
Nearest market distance (km)	0.094	−0.005	0.021	0.138	0.115	−0.001	0.015	0.075
Amount spent on food last 7 days (USD)	0.182	0.002	0.069	0.003	0.120	−0.010	0.033	0.055

Data are presented as β, 95% confidence intervals, p-value and were analyzed by multivariate regression analysis.
[a]Adjusted for district, farming system, women's education, women's age, gender of household head, education of household head, and age of household head.

3.4.2. Sociodemographic factors associated with of women's dietary diversity

Table 5 shows the results of a multivariate regression analysis of the relationship of DDS and WDDS-10 with sociodemographic variables, including wealth status, household size, nearest market distance, and amount spent on food in the past seven days. The analysis was adjusted for district, farming system, women's education, women's age, gender of household head, education of household head, age of household head and wealth status (see Supplementary Table 4 for unadjusted model outputs). Wealth status and amount spent on food in the past 7 days showed a significant positive relationship with women's dietary diversity. Wealth status was associated with higher DDS (β = 0.305, 95% CI = 0.27–0.73) and WDDS-10 (β = 0.230, 95% CI = 0.08–0.37). The results indicate that each unit increase in women's wealth status increased the DDS and WDDS-10 by 0.31 and 0.23, respectively. Women from households that spent more on food in the past seven days were associated with a higher DDS (β = 0.182, 95% CI = 0.002–0.07), but not WDDS-10 (β = 0.120, 95% CI = −0.01 to 0.03). This means that for every additional dollar spent on food in the past 7 days, the DDS increased by 0.18. By contrast, household size and distance to the nearest market were not associated with greater increase in DDS (β = 0.106, 95% CI = −0.101 to 0.15; β = 0.094, 95% CI = −0.005 to 0.021) and WDDS-10 (β = 0.125, 95% CI = −0.037 to 0.125; β = 0.115, 95% CI = −0.001 to 0.015).

4. Discussion

Here we advance the literature by comparing the dietary diversity of women from soybean and non-soybean households from rural Zambia. Overall, we report no significant difference in DDS and WDDS-10 between the two groups. We explored factors associated with dietary diversity and report that household wealth status is the most important determinant of women's diet diversity as an indicator of diet quality. Our findings suggest that dietary diversity is mediated by socioeconomic factors such as household wealth.

4.1. Effect of soybean farming on women's diets

As in other African countries, soybean in Zambia has been promoted to encourage crop diversification away from maize (a leading food and income security crop), improve cash income to farmers and nutritional security (Giller et al., 2011; Manda et al., 2017; Mubichi, 2017). However, the study finds little evidence suggesting that growing soybean resulted in higher diet diversity directly. Farmers are more motivated to grow the crop for sale than household consumption. This could be attributed to the focus of soybean promotional messages as a cash crop rather than food crop. Soybean production and processing (mostly into livestock feeds and edible oils) has increased exponentially in the past two decades. Exports for soybean products such as oilcake/meal enabled by rapid growth in livestock sectors in the Southern African region, seem to drive increased investment in industrial processing of soy (Meyer et al., 2019; Mulenga et al., 2020). Likewise, a recent study using FAO food balance sheets shows that soybean has increased contributions to the national supply dietary nutrients such a calcium, protein, energy, iron at national-level in Zambia (Kapulu et al., 2022). However, the findings from this study show that the quality of diets assessed *via* DDS and WDDS-10 of women from soybean farming households did not differ from that of non-soybean farming households. The findings demonstrate that soybean farming was not associated directly with more diverse diets. This likely because soybean is processed into oils and livestock feeds, rather than directly consumed. In this cohort, there is low consumption of animal source foods among soybean and non-soybean farming women, suggesting that there is little contribution coming from soybean as animal-feed to the diets of women. Our findings confirm what previous studies show regarding low household-level utilization of soybean for food in SSA. Therefore, there is a need to train farmers in domestic processing for soybean for food to encourage its consumption and utilization—an important enabler (Chianu et al., 2009; Wilson et al., 2021). However, this needs to go alongside interventions such as behavioral change communication focusing on consuming nutritious foods, especially the locally available ones such as eggs and fruits. Nutrition-sensitive agriculture (NSA) programmes focused on women's training in processing their produce have resulted in increased intake of nutritious foods and improved diet diversity (Gondwe et al., 2017).

This study revealed that women from soybean-growing households residing in Chibombo with better proximity to soybean and food markets, including major cities such as Lusaka and Kabwe, achieved similar diet scores compared to those living in Mkushi. This suggests that location did not seem to affect dietary diversity across differently linked to urban cities. Both districts are in rural settings, which could be a function of the diversity of food markets in such settings. For instance, a study involving 600 households conducted in Cameroon and Ghana suggests that households living in urban cities with better access to food markets were more likely to have higher DDS than those from peri-urban (agricultural) cities (Bahadur et al., 2018). Moreover, the women from the two districts had similar consumption patterns (Supplementary Figure 2). Previous reports suggest that in rural Zambian settings, the diets do not differ much, comprising mostly nshima (a thick porridge) made from maize or cassava alongside dark green leafy vegetables, which is consistent with results from this study (Caswell et al., 2018). However, a further look at the dietary composition from results of this study suggest that dietary transitions is slowly occurring among rural households as consumption of sugar and snacks is on the rise (Kapulu et al., 2022). Notably, Chibombo women consumed more meat, poultry, oil, and fats than Mkushi. This could be attributed proximity to edible oil processing plants for the women located in Chibombo.

4.2. Agricultural diversification and women's diets

The present study results showed no relationship between the proportion of crops harvested consumed with DDS and WDDS-10 (Table 3). The farms were not diversified enough with food crops to affect the diet diversity of the women. Another possible explanation for this is that soybean and many other cash crops (e.g., tobacco, groundnuts) have been promoted to increase agricultural incomes (Kumar et al., 2018). However, studies from Zambia report that direct consumption of soybean from their own produce is low due to processing constraints among smallscale farmers (Lubungu et al., 2013; Alamu et al., 2018). This is due to a lack of knowledge of soybean processing techniques such as cooking and baking (from soy-flour) for home consumption (Lubungu et al., 2013). Likewise, a survey conducted among smallholder farmers in Ghana revealed that many farmers consider soybean more of a cash crop than a food crop (Mbanya, 2011). Thus, many smallscale farmers prefer selling most of their harvest, improving their incomes (Meyer et al., 2018).

In Zambia, soybean productivity among smallscale farmers is below 1 ton/ha and is characterized by high transactional costs (Sitko et al., 2018). Farmers also have poor access to inputs and markets offering higher soybean prices (Mbanya, 2011; Asodina et al., 2020). Besides, the scale is too small to provide an adequate income to diversify the food they can purchase. Moreover, smallscale farmers tend to over-specialize when market demand for especially cash crops increases, impacting agricultural and diet diversity, respectively (Mofya-Mukuka and Hichaambwa, 2018). Recent reports from Zambia show that increasing soybean productivity and better market access seems important if smallscale farmers are to realize dietary benefits from soybean production (Nuhu et al., 2021). The study measured resultant welfare benefits from growing soybean on smallscale farmer incomes and household food security. Generally low productivity soybean and limited access to land among smallscale farmers compared to commercial farmers, affected household food security and incomes. This suggests that, while policy interventions in Zambian agriculture have focused on improving agricultural diversity, e.g., promoting soybean and emphasizing increasing rural incomes (Manda et al., 2019), there is a need to improve their access to land and increase productivity. Smallscale farmer production systems are not diverse and thus farming has little to no effect on dietary diversity.

Furthermore, results showed no relationship between FPDS (a proxy indicator of agricultural diversity) and DDS and WDDS (Table 3). In this study, most of the households in the two farming systems and districts had low diversity, and they grew less than three food crops and kept fewer than two livestock species (see Table 2). The pathway linking production diversity with women's diets is complex (Sibhatu and Qaim, 2018a; Madzorera et al., 2021). For example, contributions from farm production diversity to dietary diversity will most likely be diminished if households predominantly grow crops or keep livestock for sale and not consumption. Unlike our study, a previous rural agricultural household survey by Nkonde et al. (2021) used a 24-h recall to investigate the link between agricultural diversification and household diet diversity scores (DDS) among 7,934 households with under 5-year-old children across all 10 provinces of Zambia. They did not find a relationship between agricultural diversification and household diet diversity scores (Sibhatu and Qaim, 2018b; Sibhatu, 2019). In all these studies, better market access mediated the effects of production diversity on dietary diversity. Improved market access can improve farmer incomes from sales, which improves diets when spent on nutritious foods. Provided the markets are well-functioning and have stable supply (available) and affordable nutritious foods (Manda et al., 2018a).

Several factors that seem to mediate the relationship between diversification and diets are reported in the studies (Sibhatu et al., 2015; Sibhatu and Qaim, 2018a; Madzorera et al., 2021). These include consumption of own produce, food prices, food market availability, geographical location, and income from sales. However, while agricultural diversification can improve smallholder incomes (Jones, 2017), the results of this study show a weak association. Agricultural diversification alone, we argue, is not enough, and that there are equally important determinants of the quality and diversity of diets. It can be argued that from a nutrition-sensitive perspective, interventions such as soybean farming are not yet providing the farmers with better access to affordable markets with nutritious foods (Madzorera et al., 2021). This can be achieved with much emphasis on increasing farm income from soybean sales, investment in micro-level processing as well as sensitization on the role and importance of crop diversification more generally and soya bean expansion specifically.

4.3. Sociodemographic factors and women's diets

The sociodemographic factors revealed that household wealth was the strongest predictor of DDS and WDDS-10 among agricultural households. For example, every increase in wealth status (i.e., from poorest to poorer or middle to rich) resulted in a 0.26 (95% CI 0.25–0.7) and 0.22 (95% CI 0.08–0.37) unit increase in DDS and WDDS, respectively (Table 4). These findings are aligned with previous research in Zambia by Mofya-Mukuka et al. (2017) that used 24-h recall panel data collected from two surveys in all 10 provinces. The study involving 8839 households also found that household wealth status increased household diet diversity scores by 18 percentage points (Mofya-Mukuka et al., 2017). Further, the present study results show that women's dietary diversity (DDS and WDDS-10) improved in households with wealth status ranked middle, rich and richest, respectively. Conversely, women in poor and poorest ranked households had low diet diversity regardless of farming system and district.

Considering that the districts in this study are rural, poverty levels are high (CSO, 2016), with limited infrastructure and inadequate institutional support for market engagement. This could potentially be the reason this study did not find difference in diets between soybean and non-soybean households. A recent study shows that farmers who cultivated <5 ha soybean (i.e., smallscale) did not receive sufficient economic returns to reduce poverty, despite a wider growing market demand and soybean prices (Nkonde et al., 2021). Limited market connectivity could be another important factor.

Another key finding in this study was a positive relationship between the proportion of crops harvested and sold with DDS. The regression model was adjusted for district (Chibombo and Mkushi), farming system (soybean and non-soybean) and wealth status. It is plausible that women from households that allocated more money toward food achieved more diverse diets. A panel study in Zambia confirmed this, finding a positive association between land under soybean and increased incomes from sales with diet diversity (Nkonde et al., 2021).

This study found that the amount of money spent on food was positively associated with DDS and WDDS-10. The finding agrees with previous studies that report increased effects of income from agriculture on diet diversity (Mofya-Mukuka and Hichaambwa, 2018; Some and Jones, 2018; Mulenga et al., 2021). This study demonstrates that although crops like soybean have been promoted as cash crops, this may not always impact diet diversity if incomes earned are not sufficient. Policy measures that provide income social safety nets especially for the poor are required, including tax incentives on nutritious foods to increase availability.

Nevertheless, this was not the case for farmers who did not receive sufficient economic returns from soybean growing on <5 ha of soybean. Smallscale soybean production is characterized by low productivity. Their yields and land area were insufficient to improve their wealth despite growing market demand and soybean prices (Nkonde et al., 2021). In the case of the present study, farmers involved in soybean need to earn enough income from crop sales for soybean to improve diets *via* the income pathway.

Therefore, while the Zambian government has promoted soybean to improve rural incomes, the results from this study show that improving diet diversity among rural farming households involves complex socioeconomic factors. Some of these notable factors include food market availability, the proportion of harvest retained for consumption, the amount spent on food, household-level decision-making dynamics, women empowerment, education, and incomes from sales (Wineman, 2016; Gondwe et al., 2017; Rosenberg et al., 2018; Sauer et al., 2018; Mulenga et al., 2021). For example, women play an important role in making decisions about food purchases (Bellon et al., 2016). However, women are at a higher risk of achieving low diet diversity, especially if they are less empowered and come from low-income or poor households (Harris-Fry et al., 2015; Madzorera et al., 2021). Since poor women may find it difficult to purchase enough food, including nutritious ones, to feed the entire household, they might prioritize meeting the food needs of other family members (e.g., children and men) over their own (Chakona and Shackleton, 2017). Therefore, a better understanding of such household dynamics is needed if interventions such as soybean farming are to achieve food security and desired nutrition outcomes for women.

5. Implications of the study

Economic imperatives, specifically attractive soybean prices driven by increased market demand, seem to be the Government basis for encouraging farmers to participate in soybean production in Zambia. The framing of soybean promotional messages among smallscale farmers are primarily for income rather than food. Evidence from this study support the hypothesis that farmers may be growing soybean for markets to earn higher incomes and not for direct food consumption or healthy food purchases. This research suggested limited evidence of soybean utilization for food among smallscale farmers. There is a need to sensitize smallscale farmers, especially women, on the nutritional benefits of soybean consumption and household-level processing technologies. Future studies should further explore opportunities and barriers for household-level soybean utilization among smallholder farmers.

This study also found an important difference between households in different wealth quintiles regardless of the farming system (soybean or non-soybean). Smallscale farmers rely on market functionality to grow their incomes and access nutritious foods. Results underpin the argument that the functionality of markets such as for soybean for farmers located both nearer and further away from cities and main roads could raise challenges including price exploitation. As with other crop value chains, this increases transactional costs on the part of smallscale farmers and undermines incomes, perpetuating the poverty trap (see Manda, 2022). The policy drive to expand soybean production has not considered the dynamics among smallscale farmers; instead, as the case has been with maize, the approach is more holistic than targeted. The implication is that because most of these farmers depend on agriculture as their main livelihood activity, they may not generate sufficient incomes (in this case, soybean farming) to enable them to move out of poverty and simultaneously meet their food needs (Mdee et al., 2020). Most smallscale farmers have access to small portions of land on which they also grow other staples. Furthermore, smallscale soybean farming is characterized by low productivity and poor market functionality. The farmers are not likely to earn sufficient incomes from soybean growing until these improve (Nkonde et al., 2021). The income pathway should be complemented with additional interventions to influence income use, for example, nutrition education and women empowerment for increased decision-making on how income from agriculture including soybean production, and non-agriculture sources are used to purchase nutrient-dense food.

5.1. Limitations of study

For the first time, a study in Zambia focuses explicitly on assessing how soybean farming is associated with diet quality. However, the study has several limitations. First, the FFQ did not specifically ask questions about the consumption of soybean-based foods. Soybean was included in the FFQ as a food item under oil crops alongside other crops such as groundnuts and sunflower. Consequently, a limitation of this study is that it might not be possible to ascertain a single direct contribution to diet scores from soybean alone. In this case, dietary assessment methods that use an open 24 h recall would be fittingly relevant to assess the consumption of soybean. Therefore, caution should be applied when interpreting the results, as FFQ are good for estimating dietary patterns and not consumption of specific foods. While DDS it is a good measure of food access within the context of food security, it does not provide an indication of nutrient adequacy at the individual level (FAO, 2018) because it does not consider the nutritional quality of food groups consumed. This is particularly important considering that micronutrient deficiencies such as calcium, zinc, folate, and iron are prevalent among women in rural areas. To examine adequacy of the diet at an individual level, the WDDS-10 was used because it considers the quality of the diet by assessing the type of food groups consumed. The WDDS-10 is an easy-to-use proxy indicator for nutrient adequacy to determine diet quality when resources and time are limited (Arimond et al., 2010; FAO, 2018). The women from both farming systems had a mean DDS of 10 and consumed six food groups (WDDS-10 = 6) of the 10 required to achieve diet adequacy. Soybean was included in the FFQ as a food item under oil crops. While groundnuts are generally consumed in various forms, sunflower and soybean are mostly eaten as edible oil, represented in a different food category (i.e., oils and fats).

The study was a single time point study during the harvest months, which could change in the leaner months. Seasonality can influence dietary patterns and, consequently, the supply of dietary nutrients and nutrient adequacy (Caswell et al., 2018; Ambikapathi et al., 2019). For example, Caswell et al. (2018) shows that DDS for both women and children varied greatly across seasons in their study which involved 24h dietary recalls repeated 7 times over a period of a year. Food supply especially in rural setting could be influenced by seasonality and the geographical characteristics if the area e.g., proximity to food markets (Ambikapathi et al., 2019). Thus, future studies could design dietary assessment tools (e.g., a quantitative 24-h recall) that specifically ask questions about the consumption of different soybean foods alongside other foods and repeat this over time and across seasons.

6. Conclusion

This study has demonstrated that wealth status and income utilization are determinants of the dietary diversity of women from farming households in Zambia rather than agricultural diversification. Our study shows that diversifying small-scale agriculture through soybean farming does not appear to directly benefit diet diversity of women. Policymakers and promoters of agricultural diversification need to consider sociodemographic factors such as wealth status and market access as important drivers of dietary improvement. Policies that improve income need to be complemented with additional interventions to improve income utilization and increase soybean utilization in the household. This study provides a basis to inform nutrition-sensitive agriculture policies, including the implications of agricultural expansions to soybean on small-scale farmer livelihoods and nutrition outcomes. By better understanding the drivers and barriers, policymakers can develop appropriate strategies for improving nutritional outcomes among small-scale farming households affected by agricultural expansions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by University of Leeds (Ref No. MEEC 18-009) and in Zambia by ERES (Ref No. 2019-Apr-008). Verbal consent was given by participants in the presence of a witness, normally a local leader, or a government official. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

NK, CO, HS, JM, CN, and CC conceptualized the research. NK and HS developed the methodology. NK collected and curated the data and wrote the first draft of the manuscript. NK and MH analyzed the data. NK, CO, SM, HS, JM, CN, and CC critically evaluated the results and contributed to the writing and editing of the manuscript. CO, HS, and SM supervised the research. All authors contributed to the article and approved the submitted version.

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Conflict of interest

CC was employed by Agricultural Consultative Forum.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1115801/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Percentage of women achieving different women's dietary diversity scores (WDDS-10) and prevalence of the minimum dietary diversity for women of reproductive age (MDD-W) among soybean farmers. MDD-W = 1 if the women consumed at least five or more different food groups during the past seven days and 0 otherwise. The dotted line denotes a cut-off point for MDD-W. $N = 66$.

SUPPLEMENTARY FIGURE 2
Percentage of women from soybean households in Chibombo and Mkushi who reported consuming a food group in the past 7 days.

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