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Women, income use and nutrition quality: effects of women's decision-making in rural households in Cameroon

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Abstract

Background Women remain central to household food and nutrition security. However, they continue to face several constraints with respect to access, control and use of credit and income. There is theoretical assertion that increasing women's decision-making authority over family income increases spending and leads to gains in nutrition. However, empirical evidence on the links between rural women's income control and household food and nutrition security is inadequate, especially for a developing country, such as Cameroon.

Methodology We employ the food consumption score nutrition quality analysis, the income domain of the Abbreviated Women's Empowerment in Agriculture Index and the Partial Least Square Structural Equations Modelling to examine data collected from 600 rural households in the West region of Cameroon to establish the effects of women's control over income use on household nutrition quality. To ensure the reliability of our findings, additional tests such as the Confirmatory Tetrad Analysis, the Kolmogorov–Smirnov test with Lilliefors correction, and the Finite Mixture PLS approach are employed.

Results From the analyses, we observed that a significant percentage of households have poor nutritional quality, particularly in terms of iron-rich food consumption. Women's control over income use remains low and varies based on the source of income. The analyses show that women's decision-making concerning income use and women's perception of their decision-making ability regarding income use and expenditure are positively associated with higher nutritional quality for the household. In addition, we establish that women's perceptions of their ability to make decisions about income use have a positive direct and total effect on nutrition quality, but a negative indirect effect on the latter, with the direct positive effect outweighing the indirect effect.

Conclusions Inadequate consumption of iron-rich foods is pervasive for most households and there is limited control over income used for the majority of women in the study area. Enhancing women's control over income use has significant implications for household nutrition quality. Hence, women should be empowered to fully exploit their potential at the household level to enhance food security at the community, regional and national levels.

Keywords Nutrition quality, Rural income, Women's empowerment, Structural equations modeling, Confirmatory tetrad analysis

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Introduction

The economic viability of nation states is anchored on their ability to guarantee safe and nutritious foods not only for the working population, but to assure accessibility for all at all times. Nutrition security remains the fulcrum of the United Nations Sustainable Development Goals (SDG-2, targets 2.1 and 2.2) for the realization of comprehensive human development. Enhancing nutrition forms the basis for progress in domains, such as health, education, employment, women's empowerment, and the reduction of poverty and inequality rates. However, evidence is mounting that the objectives of ensuring access to sufficient, safe, and nutritious food for all and eradicating malnutrition in all its forms are still unattainable [1, 2].

In developing countries, women are very important to farming and rural life. Whether at the household, community or national levels, women remain important actors in the food system and the day-to-day management of nutrition. Their role is nonetheless challenged by numerous socioeconomic and political factors that impede women's access to productive resources [3]. In most of sub-Saharan Africa, for example, there is a significant difference between men and women when it comes to food insecurity and owning assets. In addition to having less access to land, credit, fertilizers, irrigation, livestock, services, and digital technologies than males do, women also face greater barriers to education, training, and work due to the greater burden of unpaid caregiving [4, 5]. Only about 15% of landowners are women [6]. Gender inequality thus remains one of the main drivers of food insecurity in Africa, as it limits agricultural production activities, women's income opportunities and plausible negative effects on nutritive consumption. In fact, the precarious situation of women has not changed much since the 2010 World Bank Gender Assessment Report [7], and the socioeconomic effects of recent events such as the COVID-19 pandemic have made it harder to reach the Sustainable Development Goals (SDGs) of achieving gender equality by 2030 [8]. Without doubt, gender inequality remains an existential threat to agricultural and rural growth, and removing these inequalities is essential for attaining sustainable food systems [4, 5, 9].

Cameroon is a typical African economy with women dominating the formal and informal sectors, yet the country continues to face several challenges, including revitalizing the economy, improving the security climate, strengthening the sociocultural fabric, and improving the population's livelihoods in a sustainable manner [10]. About 16% of households in Cameroon do not know, where their next meal is coming from. The Far North has the highest level of food insecurity, followed by the North West and the West regions [11]. Furthermore, food insecurity is more common among rural households than it is in urban households. The consumption pattern of food items, such as meat, eggs and vegetables, vary between rural and urban households [12].

In rural Cameroon, approximately 27% and 5% of households have inadequate and poor dietary habits, respectively [11]. Most food-insecure households do not consume protein- and vitamin A-rich foods on a regular basis. Iron deficiency is more severe in the Far North, Centre, and West regions, respectively. In addition, as a result of the COVID-19 pandemic approximately 63% of farming households have relied on food items with low nutritional value, such as cereals, thereby exacerbating their food insecurity status [13]. This lack of nutrients can contribute to health issues, such as anemia in both children and adults [14] Furthermore, the West region has the highest proportion of families with poor diets [11]. Nearly, 13% and 55% of households in the Bamboutos division have poor and borderline food consumption scores, respectively [15]. In stark contradiction, the agricultural sector provides livelihoods and jobs to approximately 71% of the population in the West region [11]. These challenges make Cameroon an important case study for the examination of the fundamental of food security and nutritional quality.

Some studies have examined the theme of nutrition security on the continent, and women's role in agrifood systems. Women perform important functions in the production processes in Cameroon, as in most of Sub-Saharan Africa (SSA) [16]. Globally, as of 2019, 36% of working women were employed in the agrifood systems. In most SSA countries, close to 66% of women's employment is in agrifood and they constitute more than 50% of agricultural manpower [17]. They generate 80–90% of household food [18] and are thus regarded as the primary agents of food and nutrition security and livelihoods in rural settings [19], yet they enjoy less control and access over the assets and resources, such as land, inputs, finance and modern technology, that results in the final output [16–18].

Rural women continue to face significant gender-based obstacles that restrict their prospects as economic agents and their ability to reap the benefits of their work across regions [9]. For instance, the Ministry of Women's Empowerment and the Family in Cameroon, in its National Gender Policy Document for the period 2011–2020, state that due to traditional division of labor, women are primarily responsible for household chores [20]. This responsibility falls on 60.25% of all Cameroonian women as against 39.8% of all men. Moreover, cultural norms and procedures governing control over productive assets, such as land favor men [21]. As evidenced in Cameroon, although legally men and women

are equally entitled to land ownership, the general custom is that men, not women, inherit lands [22]. Furthermore, women have limited control over household assets and the allocation of family income due to laws and customs that designates men as the household head and primary decision makers. Whereas women are anticipated to have the capacity to produce more if gender disparities in possession of and authority over productive capital are leveled [19, 23].

According to the FAO [17], improving the status of women in agrifood systems through gender parity and empowerment whether at the micro-, meso- or macro-levels [24–26] has the potential to reduce hunger, increase incomes, and strengthen resilience. Building on empowerment as important conduit for economic progress [27–29], Kawaguchi et al. [30] defines women's empowerment as "women's sense of self-worth; their right to have and determine choices; their right to have access to opportunities and resources; and their right to have the power to control their own lives, both within and outside their home". In this vein, Ntenkeh et al. [31] argue that for households to achieve food security, it is crucial for women to have the resources and opportunities to obtain nutritious food. Several studies have examined the impact of women's empowerment on household food security and child nutrition in developing countries [31–39], but they mostly rely on composite indicators of empowerment and few have zeroed on linking women's access to and control over income to nutrition security. For instance Wilunda [14] and Christian et al. [40] have emphasized the role of women's empowerment in improving children's nutritional status, specifically anemia and stunting**.**

Cognizant of the urgency to empower women, the government of Cameroon established a Ministry of Women's Empowerment and the Family tasked with developing and implementing governmental measures related to respecting and promoting women's rights and protecting the family. This institutional body manages women's empowerment centers through the ten regions of the country. The Ministry ensures that long-term development strategies implemented by the government take into account gender issues, and a national gender policy, as well as several sectorial strategies integrating gender, have been developed over the years [41]. In furtherance to the institutional framework, the Government of Cameroon adopted a National Gender Policy (2011–2020) to serve as a framework for guiding interventions in promoting gender equality and equity. The National Gender Policy (NGP) aims to contribute to the systematic elimination of inequalities between women and men at all levels of social life. However, the evaluation of the NGP and its action plan revealed some shortcomings, notably the limited effects of socio-economic support programs; the absence of actions in favor of gender equality for households and women; the prevalence of socio-cultural practices exacerbating gender inequalities in decision-making positions; low participation of women in engineering activities and their poor representation in decision-making bodies; and a weak monitoring mechanism for the policy's implementation [41]. However, this institutional arrangement is bedeviled by resource limitation and the dearth of means to implement the gender policy, especially concerning monitoring the integration of gender into other sectorial ministries. Women's empowerment initiatives that have seen relative success are those implemented by and/or with the support of external stakeholders, such as United Nations agencies, e.g., UNFPA and UN Women, as well as and other International Non-governmental organizations.

These efforts, notwithstanding, women's agency remains a contemporary challenge, particularly in assuring food security. While some studies suggest that women's empowerment can enhance food and nutrition security at the individual and household level [14, 20, 31, 34, 35, 38, 40, 42–45], others suggest that empowering women in certain domains may have adverse effects on household and individual food security [32, 46, 47]. For instance, Mataka et al. [44] suggest that empowering women in the livestock sector through decision-making in agricultural production, nutrition, and income improves household food security. Larson et al. [36] suggest that enhancing women's decision-making power over income use enhances dietary diversity. In addition, Jisso et al. [46] have shown that women's empowerment in terms of input in production and control over income reduces the prevalence of stunting. On the other hand, Aziz et al. [32] suggest that women's empowerment in the income domain has a detrimental effect on food security. Similarly, Jisso et al. [46] argue that empowering women in decision-making in production increases the likelihood of having malnourished children.

There is, therefore, feeble consensus on the effect that women's empowerment, in its various dimensions, may have on food security and the quality of nutrition [48–50]. In addition, empirical evidence regarding the specific links between rural women's control over income and household nutritional quality in Cameroon is currently nonexistent. Considering this, this study aimed at filling an empirical void by offering additional empirical proof as to the role women's control over income use could play in the quest for improved food as well as nutritional security in rural settings. Several studies have examined the connection between women's empowerment and household food security using the PLS–SEM [32, 51]. However, these studies have not thoroughly tested the robustness

of their findings, which raises concerns about the credibility of their results. This study, therefore, stands as one of the first to utilize PLS–SEM to analyze the relationship between women's empowerment and nutrition quality while also confirming the robustness of the structural and measurement model in the field of agriculture and rural development.

We, therefore, set out as our goal to provide empirical evidence on the level of women's control over income use, assess the standard of household nutrition, and uncover the nutritional implications of increased women's control over income use. From a sample of rural households in the West region of Cameroon, we apply the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) and the partial least square structural equations modeling (PLS–SEM). We observed that a significant percentage of households have poor nutritional quality. In addition, women's control over income use varies based on the source of income but remains considerably low, and women's perception of their decision-making ability regarding income use and expenditure are positively associated with higher nutritional quality for the household. These observations are instructive for policymakers and civil society organizations concerned with gender parity, rural women's empowerment, and food and nutritional security. To better contextualize our research, the remainder of this paper examines the nexus of women and nutrition security in Sect. "Women, income, and nutrition: the nexus". In Sect. "Materials and methods", we present the methodology complete with the analytical model and the source of data. The empirical results are presented and discussed in Sect. "Results ", while we conclude this paper with some policy recommendations in Sect. "Conclusion and policy implication".

Women, income, and nutrition: the nexus

There is growing concern about enhancing nutrient intake through agriculture to address the co-occurrence of nutritional deficiencies and food insecurity in rural populations [52]. Improved child nourishment is contingent upon a variety of intra-household variables and operations, which include women's roles, decision-making ability, income control, and access to and usage of sanitation and health care services [53]. In addition, improving women's rights and giving them more power through agriculture is often mentioned as a keyway to strengthen the links between agriculture, diets, and other food-related issues [54].

Women's empowerment in agriculture is critical, argues the FAO, since they are in charge of food purchase and preparation, putting them at the heart of family nutritional and food security [19]. Gender equity eventually results in greater involvement for women at the household level in aspects, such as income use. Considering that women are primary care givers, they spend a greater portion of their earnings on food, health, and care, resulting in food security [23]. However, due to the contextual differences in gender relations and disparities in levels of empowerment, the links between women's empowerment in agriculture and nutrition differ across societies [54].

Gender disparities in agriculture may inhibit the sector's ability to supply healthy foods and optimize dietary outcomes [54]. There are several connections between gender relations in agriculture and nutrition outcomes, among which is women's increased control over expenditure decisions, which leads to increased spending on women's and children's diets [33]. There is clear indication that women are more likely than men to spend additional cash on their children's nutritional needs and health in Africa, Asia, and Latin America. Women's income and resources are thus critical for nutritional and health outcomes [53].

Standardized measures of women's empowerment in agriculture, such as the Women's Empowerment in Agriculture Index (WEAI) [55], the abbreviated Women's Empowerment in Agriculture Index (A-WEAI) [56], the Women's Empowerment in Livestock Index (WELI) [57], the project-level Women's Empowerment in Agriculture Index (Pro-WEAI) [58], and, most recently, the Women's Empowerment in Nutrition Index (WENI) [59], have made it much easier to include women's empowerment metrics in surveys and studies examining the role of women's empowerment in agriculture as a mediator of nutrition outcomes at the individual and household levels [54].

Comprehensive research studies in several developing economies have found that major barriers to women's empowerment in agriculture are limited access to and control over credit, low control over how income is spent, limited autonomy in income-related decisions, too much work, not being part of a group, and limited ownership of assets [60, 61]. In several developing countries, women are not as autonomous in agriculture, because they do not have much say over how household income is spent [36, 60, 61]. The ability of women to make income-related decisions is limited and varies depending on the source of income [36]. Women are more involved in making decisions about activities that bring in money, such as non-farm economic activities and raising animals, usually chickens. Research shows that 88.3% of women in Honduras have enough power over their income [36]. In Burkina Faso, however, only 41% of women control at least one source of income [38]. Therefore, our study looks at how many women have control over how household income is spent. It focuses on the different income

streams and expenses that rural women in Cameroon's West region have control over.

In most cases, women have less control over family income than men, favoring men's spending habits, which include less money spent on food and education. As a result, increasing women's decision-making authority over family income increases childcare spending and leads to gains in nutrition and educational outcomes [62]. Furthermore, due to their lack of leverage, women in male-headed households are less likely to participate in income sharing [63]. In an analysis of intra-household decision-making over income in banana-producing households, for example, Nyabaro et al. [63] reports that 41% of rulings as to how income is spent are collectively made, 31% are made by the husband, and 28% are handled by the wife. Several studies show that women-led households spend a higher percentage of their income on household items, especially food and education, which is good for the health and education of their children [62]. Increases in women's income control have the greatest impact on early childhood dietary and nutritional practices in low-income households and households with high dependency ratios [53]. In line with the above, research by Egah et al. [64] has demonstrated that increasing women's income levels lowers the likelihood of households experiencing food insecurity. This is because improvements in women's income also boost men's income levels, and women are more likely than men to spend their income on household food expenses.

Women's empowerment is thought to lead to better nutrition [23], and women's control over money and assets is thought to improve family welfare [37, 39, 65]. Empirical work and structured analyses show that women's empowerment in agriculture is connected to higher food production, domestic dietary quality, and malnourishment [19, 35–37, 39, 65]. As a result, clearing the barriers that women face will address specific challenges in food systems, according to research. For example, Ishfaq et al. [34] found a strong and positive association between women's empowerment and food and nutrition security in Pakistan. They demonstrated that increased caloric consumption, improved dietary quality and diversity, and women's empowerment are all linked. In addition, Alam [51] shows that improving women's empowerment through enhanced ICT skills and utilization improves their nutrition knowledge.

Similarly, Ntenkeh et al. [31] and Ntenkeh [20] argue that women's empowerment enhances food security in Cameroon. Ntenkeh [20] to examine the mediating role of women's empowerment in the link between food security and household poverty in Cameroon relied on ten primary indicators and five items with multiple correspondence analysis (MCA) to construct composite indices of women's empowerment and food security, respectively. The findings show that the positive effects of food security on household poverty are indirectly transmitted through women's empowerment, thus concluding that women's empowerment partially mediates the link between food security and household poverty. In addition, Ntenkeh et al. [31] investigated the effects of women's empowerment on food security. They used seven underlying indicators (such as professional training, owning land, access to credit, etc.) to develop a composite index for women's empowerment using MCA, and a similar approach to construct a food security index. Their results revealed that households with empowered women are more food secure compared to households with disempowered women. These studies conducted in Cameroon both utilize data from the fourth round of Cameroon's Household Consumption Survey (ECAM IV). However, the survey is not explicitly tailored to assess rural women's empowerment and does not consider gender dynamics in household-level decision-making. In addition, these studies use composite indices to assess women's empowerment, overlooking the impact of individual empowerment dimensions that could offer more comprehensive insights for policy interventions.

In a study covering 31 countries in Sub-Saharan Africa [14], it was revealed that the prevalence of anemia is highest in households, where women have the least empowerment in terms of decision-making, social independence, and attitude towards violence. The authors also found that the highest prevalence of anemia among children is observed in households, where women have the least empowerment in the decision-making dimension. According to Wilunda et al. [14], increasing women's empowerment in terms of decision-making, social independence, and attitude towards violence reduces the likelihood of having anemic children. In a similar study, Christian et al. [40] demonstrated that improving the women's empowerment index is associated with a decrease in the probability of children experiencing anemia and the simultaneous presence of anemia and stunting. Specifically, enhancing women's empowerment in terms of owning assets and making decisions reduces the occurrence of anemia and the probability of both anemia and stunting coexisting in children. Therefore, empowered women can significantly contribute to improving household calorie consumption through their authority.

Gender norms vary depending on culture and context; therefore, various domains of empowerment may have distinct effects on nutrition. For example, a study conducted in Ethiopia [46] has shown that women's empowerment in terms of input in production decisions is nine times less likely to result in stunted children. In addition, women's empowerment in control over income is

negatively associated with stunting. Similar results have been obtained in Gambia [45], which provides evidence of a causal relationship between women's low educational level, low household wealth, acceptance of beating, and the prevalence of stunting and underweight among children.

According to Quisumbing et al. [2], women's income control is critical to their personal empowerment and has implications for nutrition and food security, as well as poverty reduction. Larson et al. [36] argue that when women have authority over how their money is spent, dietary diversity improves. For instance, in Nigeria, farming households produce more food of higher quality when women are able to form groups, manage their incomes, and do less work [35]. In Tanzania, women's control over financial resources and assets increases women's capacity to grow or purchase more diversified and nutrient-dense foods, improving dietary quality and feeding practices [42]. In addition, women's empowerment in agriculture has a favorable effect on household dietary patterns in Bangladesh. Similarly, in Nepal, adequacy in regards to group affiliation, income control, volume of work, and overall empowerment are linked to enhanced maternal nutrition [66]. Likewise, in Malawi, empowering women in the livestock sector through decision-making in agricultural production, nutrition, and income control boosts household food security [44]. Moreover, Jemaneh and Shibeshi [43] showed that improvements in women's empowerment as measured by the A-WEAI enhance adult caloric availability, household-level food consumption and dietary diversity scores in Southern Ethiopia.

However, under some circumstances reducing gender inequality could make women's priorities more like men's, which would mean they would spend less on their children and home expenses (Doepke and Tertilt, 2011, as cited in JICA [23]). In Pakistan, for example, women's empowerment in the income domain has a deleterious effect on food security, as higher income control by women increases food insecurity [32]. The authors justify this by stating that women typically commit a significant part of their earnings to household nutrition and child well-being; however, when women are empowered, the male householder may lessen the domestic food budget in reaction to the women's income contribution, adversely impacting food security in the household. In addition, it is claimed that in a traditional patriarchal society, where women's isolation is prevalent, there may be a poor association between women's financial status and family diet [47]. Similarly, Jisso et al. [46] have shown that women who have decision-making power in production are more likely to have malnourished children compared to disempowered women. They suggest that this could be because empowered women spend more time outside the household, leaving less time for their children's nutrition. In light of this and the associated research gaps not addressed in previous studies [67–69], the present study investigates the potential of women's control over income use to improve the quality of household nutrition in Cameroon.

Materials and methods

Study area and data collection

The field survey was conducted in the West Region (5° 30′ 0′′ N, 10° 30′ 0′′ E) of the Republic of Cameroon between July and October 2020. The region has a surface area of 13,892 km^2 and is located in the Republic of Cameroon's central-western region [70, 71]. It is the smallest region of Cameroon's ten regions in terms of surface area but has one of the highest population densities [71]. This region is chosen for the study, because it has the highest percentage of households consuming poor diets, whereas about 71% of their populations are farmers, and one-quarter of the population is involved in livestock production. Maize, beans, groundnuts, and potatoes are the most important crops grown [11].

The respondents were selected in the region through a multi-stage sampling method. In the first stage, four divisions (Noun, Menoua, Nde, and Haut-Plateau) were randomly selected out of the eight in the region; in the second stage, three sub-divisions were randomly selected per division; meanwhile, in the fourth stage, two villages per sub-division were randomly selected; and in the fifth stage, a purposive sampling technique was used to select 25 households. Therefore, a total of 600 households were selected for the study and all 600 households provided responses to the questionnaire, resulting in a 100% completion rate. The selection criteria were the presence of an adult male and female decision maker who could serve as the primary and secondary respondents as suggested in the instructional guide on the A-WEAI [66].

According to the A-WEAI instructional guide, the survey's participants were the main household decision-makers in both the social and economic spheres. The focus was on the main female decision-maker within the rural households. During the process, the main female decision-maker within the household, assisted by the survey agent, was required to fill out the questionnaire provided. In the case of polygamous households, the choice of female decision-maker was made either by randomly selecting a wife or by selecting the wife available at the time of the interview.

The data for the study were effectively collected from selected rural households involved in agricultural activities. This was done through face to face interviews using paper-based structured questionnaires. The questionnaires consisted of close-ended questions. The survey

instrument covered information on household socio-economic characteristics, household member's participation in income and expenditure decisions, and food consumption.

To assess women's control over income, respondents were asked about their involvement in decision-making regarding income from food and cash crop farming, livestock farming, and non-farm income generating activities. They were also asked about their ability to participate in decision-making regarding income from food crop, cash crop, and livestock production, non-farm activities, as well as major and minor household expenses if they wished to. In addition, household-level data on food consumption were collected to evaluate the quality of nutrition. This data covered various food groups, such as staple foods, pulses, dairy, meat, fish, eggs, vegetables, fruits, fats, sugars, and condiments. These food groups were later combined into categories of vitamin A, iron, and protein-rich foods, following the guidelines of the World Food Programme [11]. Respondents were asked to report the frequency of consuming these food groups over the past 7 days. The responses were then used to compute the nutrition quality score based on food consumption.

Method of data analysis

The analytical approach applied in this study is the agency–achievement framework (see Fig. 1), adapted from the resource–agency–achievement framework [47]. Agency has to do with women's control over income use (control over income from various sources) and the potential ability to make decisions on income from various sources. On the other hand, "achievement" refers to how well a family eats, which is measured by how much vitamin A, hem-iron, and protein-rich foods they eat.

Using the agency–achievement framework (Fig. 1), we investigated the relationship between women's agency (bargaining power regarding income use) and household achievement (quality of household nutrition). Based on the framework, we hypothesized that women's autonomy in deciding how to use family income and their confidence in making those decisions, when necessary, may lead to the purchase and preparation of nutritious diets for the household, ultimately enhancing household nutrition quality.

To achieve the study objectives, women's control over income use was evaluated through the income domain of the Abbreviated Women's Empowerment in Agriculture Index. We examined the role of the female household decision-maker in determining the allocation of household income earned by all adult household members from different activities. This includes decision-making regarding major and minor household expenses. The income is derived from a variety of sources, such as food and cash crop production, livestock farming, non-farm activities, fishing, and wages/salaries [56]. We specifically highlighted the participation of the female household decision-maker in these financial decisions.

Here, three latent variables (LVs) were built. The first latent variable, income empowerment (INCD), assesses women's ability to make effective decisions about income from various sources (food and cash crop production, livestock farming, and non-farm activities). The second latent variable, feel income empowered (FEMPW) captures women's feelings about their decision-making ability and participation in decision-making about income from food crop, cash crop, and livestock production, non-farm activities, as well as major and minor household expenses. The third latent variable, nutrition quality (NQ), is built with the frequency of consumption of vitamin A, protein, and Hem iron-rich foods in the household.

Household nutrition quality appraisal

The nutritional quality of food is linked to its content of nutrients [72]. Household nutritional quality is determined by the amount of valuable nutrients present in the food consumed. It is directly related to the value of diets in terms of physical health, growth, development, reproduction, and overall well-being of consumers [73]. The food consumption score nutritional quality analysis (FCS-N) which ascertains how often a household consumed foods rich in certain nutrients is employed to evaluate household nutrition quality. In contrast to previous

Fig. 1 Conceptual framework showing the agency–achievement framework. Source: Adapted from [47]

studies [32, 39, 42–44, 47] that relied on of the standard Food Consumption Score (FCS), Household Dietary Diversity Scale (HDDS), or Household Food Insecurity Access Scale (HFIAS) to evaluate household food security, we utilized the Food Consumption Score Nutritional Quality Analysis (FCS-N). The FCS-N surpasses these traditional indicators by emphasizing macronutrients, particularly proteins, which are essential for preventing wasting and stunting, as well as micronutrients, mainly vitamin A and hem iron. Deficiencies in these nutrients can lead to infectious diseases, such as measles, diarrhea, and malaria (up to a third of cases for vitamin A) and anemia [74]. This tool is, therefore, suitable for nutrition security assessments.

Hence, this tool focuses on three key nutrients; Protein, Vitamin A and Iron (hem iron) primarily for their nutritional importance but also that foods rich in these nutrients can be easily grouped from food consumption data. It is suitable for this study, because it provides essential information on households' dietary diversity, and food frequency and provides an additional level of information on the nutritional value of the households' diet thereby making it possible to ascertain the nutrient inadequacies within households [74]. The FCS-N analysis is based on three food groups: vitamin A, protein, and hem iron-rich foods. Protein is important, because it plays a key role in growth and is crucial for preventing wasting and stunting. Similarly, Vitamin A and Iron are also important, because deficiencies in these nutrients can lead to widespread death and disease in developing countries [74].

To conduct the FCS-N analysis, we recorded the frequency of consumption for each household's various food groups. These food groups include staples, pulses/nuts, dairy, flesh meat, organ meat, fish/shellfish, eggs, orange vegetables, dark green leafy vegetables, orange fruits, fats, sugars, and condiments. The recording was done on a 7-day recall basis. Later, the consumed food groups were aggregated into vitamin A, hem-iron, and protein-rich foods, as shown in Table 1. We also recorded the frequencies of consumption for these nutrient-rich food groups.

After adding up and sorting the different food groups into various nutrient-rich food groups, the total number of days each food group was eaten within a week (the past 7 days) was found and ranked as follows: 0 days, 1–6 days, and 7 days [74]. From the frequency thresholds, the following categories of food consumption are obtained: 0 day: food group never consumed; 1–6 days: food group consumed sometimes; and 7 days (and/or more) days: food groups consumed daily.

The number of times each nutrient-rich food group is eaten is then recoded into three groups for analysis: 0 = 0 time (never consumed), 1 = 1–6 times (consumed sometimes), and 2 = 7 times or more (consumed at least daily).

Empirical specifications

Nutrition status is an endogenous construct used to examine the effects of women's control over income use on food nutrition quality. The exogenous factor (control over how income is used) is made up of two components: the decision about how income is used and the feeling of being in charge of how income from production activities is used. These components are further divided into the input women have in decisions regarding the use of income generated from various activities, such as food crop, cash crop, livestock, non-farm activities, wage and salary, and fish farming activities. It also includes the extent to which women feel they can make personal decisions regarding income from farm and non-farm economic activities, their own wage or salary employment, as well as major and minor household expenditures [66]. Therefore, both the endogenous and exogenous factors are latent variables that are inferred from multiple observed indicators. Because the empowerment and nutrition quality constructs cannot be measured directly and are decomposable structures made up of many indicators, they can be easily analysed using partial least squares (PLS).

Table 1 Categories of FCS-N food groups

Vitamin A-rich food group		Protein-rich food group		Hem iron-rich food group	
Food groups	**Frequency of consumption(*n*)**	**Food groups**	**Frequency of consumption (*n*)**	**Food groups**	**Frequency of consumption (*n*)**
Diary		Pulses/nuts		Flesh meat	
Organ meat		Dairy		Organ meat	
Eggs		Flesh meat		Fish	
Orange vegetables		Organ meat			
Green vegetables		Fish			
Orange fruits		Eggs			

Source: Author; adapted from WFP [74]

The PLS–SEM method is very appealing for this study, because it allows for the estimation of complex models that include many constructs, indicator variables, and structural paths without requiring distributional assumptions on the data. Therefore, we employ Partial Least Squares SEM (PLS–SEM) in a novel manner to evaluate the relationship between women's empowerment and nutrition quality. The basic idea for this method was developed by [102] for multivariate analysis and was later extended to SEM.

Two different conceptual models make up the PLS–SEM. The structural model (Eq. 1) ascertains the validity and reliability between the latent causal constructs and the observed. The measurement model (Eq. 2), on the other hand, examines the significance of the relationship between the variance of the endogenous variables, the predictive power of different variables, and the latent constructs, [75]. The following equations are related to the two sub-models:

$$\xi(m,1) = B(\mathrm{m},\mathrm{m}) \cdot \xi(m,1) + \tau(m,1) \tag{1}$$

$$x(p,1) = \Lambda(\mathrm{p},\mathrm{m}) \cdot \xi(m,1) + \delta(m,1) \tag{2}$$

Here, m and p express the latent variables (LVs) related to nutrition quality, income decision, and the ability to make a decision. The manifest variables (MVs) include decisions regarding income from non-farm activities, livestock, food crops, and cash crops. It also includes the ability to make decisions about income from non-farm activities, livestock, food crops, cash crops, minor and major household expenses, as well as the frequency of consuming Vitamin A, protein, and iron-rich foods. The vectors (m,1) and (p,1) in this study are vectors of the three (03) latent variables and the vector of the 13 manifest variables respectively. The ξ, x, B, Λ, τ and δ specify the LV and MV vectors, the path coefficients of the LVs, the factor loading joining the MV to the LV, and the errors terms, respectively. Higher order LVs were not considered in Wold's basic PLS model. Two popular approaches for dealing with hierarchical constructs are the repeated indicators approach [76] and the two-step approach [77].

The hierarchical component model (HCM) is a structure comprised of multiple layers of constructs. It consists of two main elements: the higher order component (HOC) and the lower order components (LOCs). The HOC represents the more abstract, higher order entity, while the LOCs capture the subdimensions of the higher order entity. Each type of HCM can be characterized by different relationships between two things: (1) the HOC and the LOCs, and (2) the constructs and their indicators. These relationships can be either formative or reflective. In a reflective measurement or model, the manifest variables (MVs) are influenced by the latent variable(s) (MVj < = LVi). However, in a formative construct model, this relationship is reversed (MVj = > LVi) [78].

Four hierarchical constructs models have been considered in previous studies, and these constructs were used to show different relations between the higher order constructs (HOCs), low-ordered constructs (LOCs), and their indicators [79]: reflective–formative, reflective–reflective, formative–reflective, and formative–formative [80]. In this study, we utilized the reflective–formative HCM, which incorporates reflective indicators in the measurement models connecting LOCs and manifest variables. In addition, it incorporates the formative link between the LOCs and the HOC of the structural model. The reflective measurement model is appropriate for this study, because it allows the latent variables to determine the manifest variable. For example, if a woman has control over the use of income, it implies that she should have a say in decisions about income generated from various activities. She should also feel empowered to make decisions regarding income from wages, employment, and major household expenditures [66]. This model is infrequently used in the structural model. PLS–SEM is the standard framework to measure this hierarchical model.

Repeated indicators approach [103] suggested an approach for modeling hierarchical constructs known as the repeated indicators approach. This approach replicates MVs numbers at each construct [80]. For this approach to stand, the models should have all reflective indicators in the first- and second-order factors. The following three equations were used to model the repeated indicator approach:

$$\xi^{I}_{m,1} = B_{m,q} \cdot \xi^{\mathrm{II}}_{q,1} + \zeta_{m,1} \tag{3}$$

$$x_{p,1} = \mathrm{A}_{m,q} \cdot \xi^{I}_{m,1} + \delta_{p,1} \tag{4}$$

$$x_{p,1} = \mathrm{A}^{II}_{p,1} \cdot \mathrm{A}^{II}_{1,1} + \delta_{p,1} \tag{5}$$

In the model, m and p are the subscripts for the number of first-order LVs and the MVs. Subscript q indicates the total number of second-order LVs. The vectors ξ_{I}, ξ_{II}, x, ζ, δ and ε are the LVs, the first- and second-order MVs, and the structural and measurement errors, respectively. The matrices B, Λ_{I}, and Λ_{II}, represent the path coefficients linking the LVs and the factor loading linking the MVs to the LVs of the first and second-order constructs, respectively. A limitation of this approach is that, when using PLS estimation, variables of a similar nature link together and create bias.

Two-step approach This approach is another alternative way to build Higher Order Constructs (HOCs). Notably, all LOCs (income decision and feel can make decisions about income use) are reflective. It is a well-known best-fit approach for analyzing reflective indicators in HOC models [81, 82]. Here, we primarily estimate the model's LVs (income decision and feel can make decisions) without second-order constructs [77]. A separate higher order structural model is analyzed with the use of LV scores, where we regress nutrition quality on income decision and feel can make decisions. This approach involves two stages. The first stage considers the first-order LVs estimations in the measurement model:

$$x_{p,1} = \Lambda^{I}_{p,m} \cdot \xi^{\mathrm{II}}_{m,1} + \delta_{p,1} \tag{6}$$

The estimated scores $\widehat{\xi}$ and I obtained in the first step are used as indicators for the second-order LVs in the second stage.

$$\xi^{I}_{m,1} = B_{m,1} \cdot \xi^{\mathrm{II}}_{1,1} + \zeta_{m,1} \tag{7}$$

One disadvantage of this approach is that it does not consider stage two's construction when evaluating the scores of LV during stage one. But [104] has shown that the method used does not matter for second-order construct consistency. In addition, this method does not give biased or unreliable estimates like the repeated indicators method does when the sample size is small. Consistent with previous studies, [79, 81, 82], a two stage path approach is applied in this study, and data were analyzed with STATA and R [82].

After estimating the results, we proceed to the robustness checks to assess the sensitivity of our findings. Recent research has proposed methods for evaluating the robustness of PLS–SEM results [78, 83]. These strategies specifically focus on either the measurement model or the structural model. Gudergan et al. [84] introduced the confirmatory tetrad analysis (CTA–PLS) as a method for empirically supporting the specification of the measurement models (i.e., reflective versus formative). The CTA–PLS method is based on the use of tetrads, which describe the discrepancy between the product of one set of covariances and the product of another set of covariances [75, 85]. For the structural model we follow Hair et al. [78] and analyse (1) the potential nonlinearity of the effects, (2) endogeneity and (3) the unobserved heterogeneity.

Results

Household socioeconomic characteristics

Table 2 depicts the characteristics of participants and their households. According to our observations, 67.7% of the sampled women were members of dual-headed households, 19.7% were members of single female-headed households, and 12.7% were members of single male-headed households. The household structure has important implications for women's agency and, therefore, affects their control over income use. Statistics further indicate that the women had an average age of approximately 45 years, with an average household size of close to six persons per household. The statistics further depict that 6% of women are illiterate. About 22% and 55% of the women have received primary and secondary education, respectively. Women with a university level of education make up about 17.2% of the surveyed respondents. Women's education level plays a significant role in food management and women's agency as well. The majority of respondents are married (71%), and the most common religious belief is Christianity (59.8%). Crop production appears to be the most important agricultural activity for the majority of respondents (81.7%), while only 43% receive agricultural extension services and 22.5% belong to producer organizations.

Table 3 shows the state of household nutrition quality as measured through the consumption frequency of vitamin A-rich foods, protein-rich foods, and hem-iron-rich foods. It appears that in the study area, the nutrition quality was not much worse than the national average. Roughly 6.2% of households in the study area do not consume vitamin A foods, 4.5% do not consume protein-rich foods, and 8% do not consume iron-rich foods. This result differs from those obtained by WFP [11] in 2017, which showed that approximately 4.8% of rural households do not consume vitamin A-rich foods on a weekly basis, 6.2% do not consume protein-rich foods on a weekly basis, and 22.3% do not consume iron-rich foods on a weekly basis. While noting improvements concerning protein and iron-rich foods, we observe that the situation for vitamin A foods has rather worsened when compared to the national average.

Concerning women's control over use of income (Table 4), about 23.5% of women regularly made decisions about income earned from non-farm activities, 20.50% on income earned from food crop production, 17% on income from cash crop production, 13.83% from livestock production and wages and salary occupations, respectively, and 3% on income from fishing. The relatively low proportion of women making decisions on income utilization from various sources can be because food crop production is mainly carried out for subsistence purposes, and only the excess is usually sold to settle specific problems, such as health issues and sponsor children's education. On the other hand, cash crop and livestock production are mainly controlled by male household heads who, therefore,

Table 2 Household characteristics (n = 600)

Variable	Definition	%	Mean	Std. deviation
Household structure	Dual headed	67.70	1.45	0.708
	Single female-headed	19.70		
	Single male headed	12.70		
Age of household head	Continuous		44.948	11.866
Household size	Continuous		5.688	3.758
Female decision makers' level of schooling	No formal education	06.00	2.835	0.776
	Primary education	21.70		
	Secondary	55.20		
	University	17.20		
Households' main economic activity	Crop production	56.00	1.835	1.082
	Livestock production	16.50		
	Trade	15.50		
	Public service	12.00		
Marital status	Single	12.00	2.187	0.816
	Married	71.00		
	Divorced	03.30		
	Widower	13.70		
Belief	Christian	59.80	1.787	1.013
	Muslim	06.00		
	Traditionalist	29.80		
	Other	04.30		
Membership in producers' organisations	No	77.50	1.225	0.418
	Yes	22.50		
Household's main agricultural activity	Crop	81.70	1.183	0.387
	Livestock	18.30		
Access to agricultural extension services	No	57.00	1.43	0.495
	Yes	43.00		

Table 3 Household nutrition quality for respondents and their households (*n* = 600)

Food group	Definition	%	Mean	Standard deviation
Vitamin A	Never consumed	6.2	1.63	0.5975185
	Consumed sometimes (1–6 times)	24.7		
	Consumed at least daily (7 times or more)	69.2		
Protein	Never consumed	4.5	1.678333	0.5556183
	Consumed sometimes (1–6 times)	23.2		
	Consumed at least daily (7 times or more)	72.3		
Hem-Iron	Never consumed	8.0	1.181667	0.5560388
	Consumed sometimes (1–6 times)	65.8		
	Consumed at least daily (7 times or more)	26.2		

dispose of the money earned without necessarily consulting their female counterparts. In addition, few women are involved in wage and salary occupations in the rural milieu (those who are limited to temporary jobs, such as farm workers during planting and harvesting periods), and more to that, the practice of fishing is very limited in the study area (only close to 6% of respondents are involved in fishing).

With respect to women's impressions about their ability to make decisions about income use, a majority of women declare feeling they can make decisions about income from food crop production (63.33%), major

Table 4 Women's participation in decision-making for income use

Women's control over income use	Percentage
Decision-making on income earned	
Makes decisions on income from food crop production	20.50
Makes decisions on income from cash crop production	17.00
Makes decisions on income from livestock production	13.83
Makes decisions on income from non-farm activities	23.50
Makes decisions on income from wages and salaries	13.83
Makes decisions on income from fishing	03.00
Feel can make a decision on income and expenditures	
Feel can make a decision on income from food crop production	63.33
Feel can make a decision on income from cash crop production	45.50
Feel can make a decision on income from livestock production	47.67
Feel can make a decision on income from non-farm activities	49.17
Feel can make a decision on income from fishing	05.50
Feel can make a decision on income from wage/salaries activities	28.33
Feel can make a decision on major household expenditure	72.50
Feel can make decision on minor household expenditure	75.50

household expenditure (72.5%), and minor household expenditure (75.5%). About half of women reported they feel they can make decisions on income from non-farm activities (49.17%), income from livestock production (47.67%), and income from cash crop production (45.5%).

The above results align with the previous study of Nikiema et al. [38], which demonstrated that in Burkina Faso, only 41% of women have control over at least one source of income. In addition, as suggested by Larson et al. [36], women's ability to make decisions about income is restricted and varies by the source of income. Women appear to be more autonomous when it comes to decisions over income from non-farm activities and food crop production, sometimes, because their male counterparts consider such income as being relatively insignificant in terms of volume and seasonality. As a result, our findings differ from those of Larson et al. [36], who assert that in Honduras, 88.3% of women have adequate income empowerment.

Structural model

In the first step, the latent variables (LVs) were estimated using a reflective measurement model. When considering the items' reliability, the constructs' (latent variables) relevance and convergence validity, as well as the model's discriminatory validity, we conclude that the reflective measurement model as a whole is of good quality, as shown in Table 5.

In this study, only indicators with factor loadings above 0.5 were kept (see Table 5), and all indicators with factor loadings below 0.40 were automatically taken out of the estimations. This is because the theory holds that item reliability is good when loadings are above 0.708 [78]. On the other hand, indicators with very low factor loadings (below 0.40) should always be eliminated from the measurement model [86]. Hence, all indicators used in this study have factor loadings above 0.5, which guarantee the reliability of items in the model. The loadings for all the items are above 0.5 suggesting that the constructs explain more than 50% of the indicator's variance. Hence, the loadings between nutrition quality and the consumption of vitamin A, protein and hem iron-rich foods are respectively 0.953, 0.915 and 0.656. This implies that the construct (nutrition quality) accounts for 95.3%, 91.5% and 65.6% of the variations in the consumption of vitamin A, protein and hem iron-rich foods, respectively.

The analyses also show that the model has a moderate in-sample predictive power with an R^2 of approximately 0.303 (Table 5). It implies that about 30.3% of nutrition quality was accounted for by women's control over income use (making decisions about income use and impression about the ability to make decisions about income use). The R^2 in this study appears to be small, but it is a function of the number of predictor constructs, so the greater the number of predictor constructs, the larger the R^2. As a result, while R^2 values of 0.90 may be plausible when measuring concepts, such as physical processes, similar R^2 value levels in a model that predicts human attitudes, perceptions, and intentions likely indicate an over fit [78].

The internal consistency reliability of the model is assessed with Cronbach's alpha. Internal consistency reliability refers to the extent to which indicators measuring the same construct are associated with each other. When

Table 5 Standardized loadings of measurement model—($n=600$)

	Reflective: income decision	Reflective: feel can make decision	Reflective: nutrition quality
Decision on income from a non-farm activity	0.655***		
Decision on income from livestock	0.717***		
Decision on income from food crop	0.788***		
Decision on income from cash crop	0.790***		
Feel can make decision on income from a non-farm activity		0.582***	
Feel can make decision on minor household expenses		0.807***	
Feel can make decision on major household expenses		0.782***	
Feel can make decision on income from livestock		0.649***	
Feel can make decision on income from food crop		0.799***	
Feel can make decision on income from cash crop		0.714***	
Consumption of Vitamin A-rich foods			0.953***
Consumption of protein-rich foods			0.915***
Consumption of Hem iron-rich foods			0.656***
Cronbach	0.721	0.817	0.828
DG	0.827	0.869	0.886
rho_A	0.728	0.821	1.081
Model general characteristics			
Average R2	0.30292		
Average commonality	0.57948		
Path Absolute Gof	0.41897		
Relative GoF	0.75149		
Average redundancy	0.16624		

***=Significant at 1% level; Average R-squared

Table 6 Discriminant validity—squared interfactor correlation vs. average variance extracted

	Income decision	Feel can make decision	Nutrition quality
Income decision	1.000	0.598	0.001
Feel can make decisions	0.598	1.000	0.006
Nutrition quality	0.001	0.006	1.000
AVE	0.546	0.529	0.725

Table 7 Standardized path coefficients of latent variables

Variable	Income decision	Nutrition quality
Income decision		0.63**
		(0.030)
Feel can make decision	0.773***	0.129**
	(0.000)	(0.046)
Adjusted R2	0.597	0.55

p values in parentheses (*** and ** = significant at 1% and 5%, respectively)

using Cronbach's alpha, the higher the values, the higher the levels of reliability; thus, a Cronbach's alpha of 0.72 to 0.83 indicates that the internal consistency reliability is satisfactory.

The convergence validity is assessed with the analysis of the average variance extracted (AVE). In our model, the mean AVE are satisfactory varying between 0.546 and 0.725 (Table 6), implying that the constructs income decision, feel can make decision and nutrition quality each converges to explain 54.6%, 52.9% and 72.5% of the variance in their items. The following table (Table 6) is used to verify the discriminant validity criterion. The interfactor correlation reflects the correlation between the different constructs (income decision, feeling capable of making decisions and nutrition quality). The discriminant analysis is validated when the squared value of this correlation is lower than the corresponding AVE for all the constructs [82]. Since the AVE for all constructs is above the square interfactor correlation, we conclude that the analysis meet the discriminant validity criteria.

Table 7 shows the direct relationship between women's control over income use and nutrition quality with their respective path coefficients. The results show that the

hypothesized paths of income decision and feeling like one can make a decision are highly significant ($p=0.05$). The results in Table 7 demonstrate the strong positive association between income decision and household nutrition quality ($\beta=0.63$, $p=0.030$) and suggest that household nutrition quality can be improved through this component. The income decision in this study is women's decision-making on income earned from food crop production, cash crop production, livestock production, and non-farm income activities. Hence, increasing women's income decision-making power can raise the likelihood of having adequate nutrition quality by 63%. This suggests that women who have autonomy over household income management are more likely to decide on the quantity and quality of food consumed by the household. They will prioritize balanced and diversified meals for the household.

Moving on to women's feelings about their ability to decide on income use if they wanted to, the results show that this aspect has a relatively weak but positive and significant effect on household nutrition quality ($\beta=0.129$, $p=0.046$), implying that self-confidence in one's ability to make a decision over income earned from various sources increases the likelihood of having better nutrition quality by 12.9%. The positive contribution of women's feelings about their ability to decide on income use for nutrition quality could be attributed to the fact that women's positive feelings about their ability to decide on income use are strongly correlated with effective decision-making abilities regarding household income usage. This, in turn, promotes the purchase and preparation of nutritious meals for the household.

These results are consistent with prior studies showing that women's control over income has important implications for food and nutrition security. Previous studies have shown that when women have control over how household income is spent, their diets are more varied [36], and they can buy more nutritious and varied foods for their families [42]. The positive effect of women's empowerment in terms of control over income use on nutrition quality is consistent with those of Mataka et al. [44] who have shown that household diets are more varied in homes, where women have joint or sole authority over how to use the money earned from both farming and non-farm activities.

In addition, the results in Table 7 reveal that women's feelings about their ability to make decisions is strongly and positively associated with their effective decision-making over income use ($\beta=0.773$, $p=0.030$). This shows that women who feel they could make decisions about income if they wished are 77.3% more likely to effectively make decision over household income use. Therefore, increasing women's self-confidence about their bargaining power is highly correlated with their ability to take actions and gain autonomy. This suggests that a direct and an indirect effect may exist between women's feelings about their ability to make decisions over income and expenditure and household nutrition quality.

Table 8 presents the construct's direct, indirect, and total effects on the target construct (nutrition quality). The findings at this stage reiterate that income decisions and the feeling that one can make decisions have positive direct effects on household nutrition quality, as suggested in Table 7. However, women's perceptions of their ability to make income and expenditure decisions have both a direct and indirect impact on the nutrition quality of their households. Meanwhile, the direct effect is positive ($\beta=0.129$), the indirect effect is rather negative ($\beta=-0.048$) and the total effect is, therefore, positive but with a relatively weak coefficient ($\beta=0.080$).

The negative indirect effect implies that women's feelings about their ability to decide about income use reduce the probability of having adequate nutritional quality by 4.8%. This negative indirect effect may be because increased women's self-confidence may disrupt the household's gender dynamics, and women may, therefore, face restrictions concerning their contribution at various levels within the household. In some cases, increased women's self-confidence and autonomy may result in conflicts between male and female decision-makers. In extreme cases, this gender-based violence, separation or divorce, all of which have deleterious effects on household food security and overall well-being. In addition, Aziz et al. [32] exhibited a similar outcome, revealing that women generally devote an important part of their income to household food security and child well-being, but when they are empowered, the male household head may reduce the household food budget in response to the women's income contribution, and this negatively affects household food security.

Overall, the total effect indicates that women's perceptions of their ability to make income and expenditure decisions increase the likelihood of having better nutritional quality by 8% (Table 8). This confirms that women's feelings about their ability to make decisions about income use are positively associated with adequate nutrition for households, as presented in Table 7. Therefore, enhancing rural women's decision-making power over

Table 8 Decomposition of total effects

Effect	Direct	Indirect	Total
Income decision = = > Nutrition quality	0.63		0.63
Feel can make decision = = > Income decision	0.773		0.773
Feel can make decision = = > Nutrition quality	0.129	− 0.048	0.080

household income use and building their confidence about their ability to make decisions about income use if they wish to generate positive effects on household nutrition quality.

Robustness checks

To check the robustness of the results, a series of supplementary analyses was conducted on the data [87]. These analyses aimed to assess the robustness of the measurement model through confirmatory tetrad analysis (CTA–PLS), as well as the robustness of the structural models in relation to (1) potential nonlinearity of effects, (2) endogeneity, and (3) unobserved heterogeneity [78].

Measurement model: confirmatory tetrad analysis

The CTA–PLS is a significant tool for assessing the measurement model of a latent variable and determining its nature as formative or reflective. This test requires a minimum of four indicators per measurement model. In reflective models, the nonredundant vanishing tetrads should have residual values close to zero. Deviation from zero in any of these tetrads indicates rejection of the reflective model and suggests considering a formative specification instead. The CTA–PLS utilizes tetrads to compare pairs of covariances [78].

We employ the CTA–PLS to evaluate two models: the first model links the latent variable income decision to 11 items, with 4 items theoretically linked to income-related decisions and 7 items theoretically linked to the feelings of being able to make decisions about their income (feel can make decision). The second model is the estimated model in the results section. The choice of this order serves the sole purpose of making the estimations possible.

The first column in Table 9 represents the replication number, while the next three columns provide the Chi-square test statistic, degrees of freedom, and the *p* value for the first model. The second set of three columns presents the same information for the second model, and the third set of three columns displays the results for the nested tetrad test. Since the option "reps" was specified with five replications, the output shows five test statistics based on randomly selected sets of vanishing tetrads.

A non-significant Chi-square test suggests that the first model aligns with the data. Contrary to the literature [32, 83], the results as expected, indicate that the model with one factor is inconsistent with the data, while the model with two factors (model 2) is consistent with the data. In addition, the model with two factors represents a significant improvement over the model with one factor. This pattern of results is consistent across all five replications.

Structural model: potential non-linearity of the effects

We verified the presence of nonlinear effects by following the guidelines established by Svensson [88] and conducting two examinations. First, we applied RESET test [89] on the latent variable scores obtained from the convergence of the PLS–SEM algorithm of the original model. The findings suggest that neither the partial regression of nutrition quality on income decision and feel can make decision ($F(3, 591) = 1.00$, $p = 0.3940$) nor the partial regression of income decision and feel can make decision ($F(3, 594) = 0.61$, $p = 0.6058$) is subject to nonlinearities.

Subsequently, we incorporated interaction terms to capture the quadratic impact of both income decision and the ability to make decisions on nutrition quality. The outcomes of bootstrapping with 5000 samples, without considering any sign changes, suggest that none of the nonlinear effects are statistically significant (Table 10). Thus, we can deduce that the linear effects model is robust.

Consistent with Hult et al. [90] the evaluation of potential endogeneity is conducted using a systematic procedure that begins by applying Gaussian copula approach [91]. This approach utilises the latent variable scores obtained from the original model estimation as input. Initially, we ascertain whether the variables that may potentially display endogeneity are not distributed in a normal pattern. To analyse the relationship between income decision and the ability to make decisions, we employ the Kolmogorov–Smirnov test with Lilliefors correction [92] on the latent variable scores. These scores are used as independent variables in the partial regressions

Table 9 CTA–PLS results

	Model 1			Model 2			M1–M2		
Rep	Chi-sq	*df*	*p* val	Chi-sq	*df*	*p* val	Chi-sq	*df*	*p* val
1	267.9610	35	0.0000	161.3071	34	0.0000	106.6539	1	0.0000
2	261.1947	35	0.0000	173.6134	34	0.0000	87.5813	1	0.0000
3	57.3691	35	0.0000	240.3857	34	0.0000	183.0166	1	0.0000
4	272.3312	35	0.0000	232.9020	34	0.0000	39.4292	1	0.0000
5	244.8824	35	0.0000	214.1816	34	0.0000	30.7008	1	0.0000

Table 10 Nonlinear effects

Nonlinear relationships	Coefficient	*p* values	f^2	Ramsey's RESET
INCD*INCD = = > NUTQ	0.003	0.816	0.048	$F(3, 591) = 1.00, p = 0.3940$
FMDEC*FMDEC = = > NUTQ	0.012	0.552	0.036	
FMDEC*FMDEC = = > INCD	− 0.040	− 4.100	0.016	$F(3, 594) = 0.61, p = 0.6058$
NUTQ*NUTQ = = > INCD	0.002	0.027	0.070	

Table 11 Gaussian copula approach

Relationship	Model	Path		Copula	
		β	*t*	*β*	*t*
NUTQ < = = INCD	1	0.697	9.09 ***		
NUTQ < = = INCD	2	0.664	9.02 ***	0.081	0.34
NUTQ < = = FMDEC	1	0.271	3.34 ***		
NUTQ < = = FMDEC	2	0.414	3.62 ***	0.781	2.46
NUTQ < = = FMDEC, INCD	1	0.571	7.56 ***		
NUTQ < = = FMDEC, INCD	2	0.874	3.57 ***	−0.332	−1.29

***$p < 0.001$

of the PLS path model. The results indicate that the scores of none of the components follow a normal distribution, which enables us to apply the Gaussian copula technique [91]. The results in Table 11 show that none of the Gaussian copulas (i.e., income decision and ability to make decision) are significant (p value > 0.05). Hence, we conclude that endogeneity is not present, which supports the robustness of the PLS–SEM results [90].

In addition, we checked for endogeneity resulting from the presence of omitted variables in our attempt to explain the dependent variable [93]. To address this, we followed the approach suggested by Antonakis [94] and included household size, age of household head, and household structure as control variables. After incorporating these control variables, we re-ran the PLS method and found that the results remained unchanged from before the control variables were included. This indicates that the omitted variables are now accounted for in our model.

Structural model: potential unobserved heterogeneity

The most popular methods developed so far in the literature for detecting and estimating unobserved heterogeneity in PLS–SEM are the response-based unit segmentation in PLS–SEM approach (REBUS–PLS) [95, 96] and the finite mixture PLS (FIMIX–PLS) approach [97]. Following [98] we apply the FIMIX–PLS approach which uses information criteria to determine the potential number of segments.

Table 12 Fit indices for the one-to-five-segment solutions

Groups	1	2	3	4	5
AIC	1700.335	1653.124	1627.777	1588.328	**1579.009**
AIC_3	1703.335	1660.124	1638.777	1603.328	**1598.009**
AIC_4	1706.335	1667.124	1649.777	1618.328	**1617.009**
BIC	1713.525	1683.903	1676.143	**1654.282**	1662.551
CAIC	1716.525	1690.903	1687.143	**1669.282**	1681.551
HQ	1705.469	1665.106	1646.605	1614.002	**1611.53**
MDL_5	**1790.289**	1863.017	1957.608	2038.097	2148.717
LnL	**− 847.167**	− 819.562	− 802.888	− 779.164	− 770.505
EN		0.554	0.538	0.418	**0.411**
NFI		0.655	0,548	0,362	**0.321**
NEC		**6.717**	6.871	7.114	7.425

AIC Akaike's information criterion, *AIC3* modified AIC with factor 3, *AIC4* modified AIC with factor 4, *BIC* Bayesian information criteria, *CAIC* consistent AIC, *HQ* Hannan Quinn criterion, *MDL5* minimum description length with factor 5, *LnL* Log Likelihood, *EN* entropy statistic, *NFI* non-fuzzy index, *NEC* normalized entropy criterion, *na* not available, numbers in bold indicate the best outcome per segment retention criterion

In accordance with Mathews et al [99], we began the process by assuming a single-segment solution and applying the default parameters for the stop criterion (10–10 = 1e-10), the maximum iteration count (5000), and the number of repeats (10). To determine the maximum number of segments to extract, we calculated the minimum sample size needed to estimate each segment [83, 100]. Based on a post hoc power analysis with an assumed effect size of 0.15 and a power level of 80%, it is recommended to have a minimum sample size of 85 to extract a maximum of five segments. Therefore, we repeated the FIMIX–PLS procedure with two to five segments, maintaining the same conditions as in the original analysis.

The fit indices for the one-to-five-segment results yield inconclusive findings (Table 12). Sarstedt et al. [101] demonstrated that when AIC3 and CAIC yield the same number of segments, it is very likely that these results represent an accurate number of segments. Our analysis suggests that AIC3 offers a solution with five segments, while CAIC predicts a solution with four segments.

Sarstedt [101] additionally observe that AIC4 and Bayesian information criteria (BIC) are often effective

in determining the number of segments in FIMIX–PLS. Although the AIC4 criteria indicate a solution with five segments, the latter indicates a solution with just four segments. In addition, the sample could exhibit a high level of clustering, with five segments, as determined by the EN criterion [93]. A two-segment solution also fulfils the minimum sample size criteria for each segment and is specified by the normalised entropy criterion NEC (Table 12).

Nevertheless, the minimum description length with a factor of 5 (MDL5) likewise suggests a solution consisting of only one segment. This criterion has demonstrated a clear tendency to underestimate the number of segments. Therefore, it is advisable for researchers to extract a larger number of segments than what is suggested by MDL5 [93]. In aggregate, the analyses do not firmly indicate a certain segmentation solution due to the fact that (1) AIC3 and CAIC suggest varying numbers of segments, and (2) MDL5 recommends a solution with only one segment. Thus, we posit that the level of unobserved heterogeneity is not significant, thereby validating the findings of the overall data set's analysis.

Conclusion and policy implication

Over the previous year, food and nutrition security as well as women's empowerment and gender equality have been some of the top priorities on the development agenda for most governments and international development agencies. In the context of rural Cameroon, no previous study explored the nature of women's empowerment in agriculture in general and women's control over income use in particular through the Abbreviated Women's Empowerment in Agriculture Index methodology and its effects on household food and nutrition security. This study reiterates the role of women's control over income use in enhancing household nutrition quality in rural settings. The household nutrition quality analysis highlights an inadequate consumption of iron-rich foods for most households and limited control over income used for the majority of women in the West region of Cameroon. Our result shows that rural women in the study area are vulnerable to discrepancies in terms of decision-making over income use and expenditure. Whereas women's ability to make decisions regarding the use of income and their perceived ability to make decisions over income use and expenditure both enhance household nutrition quality, to improve the food and nutrition security conditions of the rural population, nutrition education efforts should be reinforced through various channels. The caveat of this study is that women's control over income and agency with respect to income and expenditure-related issues should be considered as areas of focus when designing rural development strategies. Finally, culturally biased attitudes should be addressed to enable women to fully exploit their potential and enhance development at the family, community, and national levels.

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Author contributions
Soh Wenda B. D (PhD): Conceptualisation, data collection, writing original draft, writing review, editing and submission of article. Fon D. Engwali (Professor): Conceptualisation, validation, revision and editing. Ernest L. Molua (Professor): Contextualisation, rewriting, proofreading and editing. Mr. Longang S. Gamo: Methodology and data analysis.

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Availability of data and materials
The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate
All respondents who contributed to the study willingly agreed to participate as and confirmed through a verbal agreement.
Respondents were also made aware that they were free to stop participating at any point during the survey in case of discomfort or discontent.

Consent for publication
All authors read and are in support of article submission and publication.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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