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NUTRITIONAL COMPOSITION OF LEAST-COST STAPLE FOOD SOURCES OF NUTRIENTS IN EASTERN UGANDA

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ABSTRACT

Food cost and seasonal availability are important determinants of food choice and ultimately nutrient intake. This study aimed at establishing the nutritional composition of least-cost staple food sources of nutrients in Kamuli, Buyende and Pallisa districts in eastern Uganda across the cropping seasons. The World Food Programme (WFP) Vulnerability Analysis and Mapping (VAM) Market Analysis Tool guidelines were used to conduct a mini-survey to determine seasonal prices and availability of foods. Retailers (n= 268) from six markets in Kamuli, three in Buyende and six in Pallisa were interviewed. The least-cost sources of energy, protein, iron and zinc were determined using nutrient-cost values. The nutrient composition of the least-cost foods were determined using standard methods. For the first dry season, the least cost sources of energy, protein, iron and zinc were maize (0.052 $/1000kcal), soybeans (0.016 $/10g), maize (0.070 $/10mg) and maize (0.086 $/10mg), respectively. For the second dry season, the least cost sources of energy, protein, iron and zinc were maize (0.052 $/1000kcal), soybeans (0.015 $/10g), maize (0.070 $/10mg) and maize (0.086 $/10mg). For the first rainy season, the least cost source of energy was sorghum (0.074 $/1000kcal), protein was groundnuts (0.019 $/10g), iron was sesame (0.100 $/10mg) and zinc was sweet potatoes (0.123 $/10mg), respectively. For the second rainy season, the least cost sources of energy, protein, iron and zinc were sorghum (0.049 $/1000kcal), groundnuts (0.016 $/10g), sesame (0.067 $/10mg) and sweet potatoes (0.082 $/10mg), respectively. The richest sources of energy, sugars and starch, protein, fat, fibre and iron were sesame (797.2 ± 116.84 Kcal/100g), sweet potatoes (11.5 ± 1.22 and 86.8 ± 10.75 g/100g), soybeans (40.7 ± 4.58 g/100g), sesame (52.9 ± 3.82 g/100g), soybeans (7.0 ± 0.32 g/100g), groundnuts (7.0 ± 0.82 mg/g). The nutrition composition of least-cost foods in the dry seasons and rainy seasons indicates that they can be used to formulate low-cost nutrient-dense mixtures for the respective seasons.

Key words: Uganda, cropping seasons, least-cost, energy, protein, iron, zinc

INTRODUCTION

Adequate nutrition is essential for human development and socioeconomic well-being [1]. However, achieving adequate nutrition, especially in low-resource settings is a challenge. Undernutrition negatively correlates to wealth [2] as high food prices and low household incomes can limit access to food by reducing purchasing power [3]. Nutritious diets inevitably come at higher costs [4], costing a household seven times more than a diet that only meets the energy requirements [2]. As a result, low-income households purchase and consume greater amounts of cheap, energy-dense meals that are satisfying but have lesser nutritional content than diets in higher-income households [5]. Food prices are thus a key indicator of the food security situation in an area [6].

Food prices generally fluctuate throughout the year [7], varying across cropping seasons and locations due to agroecological zones and consumption patterns [8]. Agriculture in Uganda is strongly dependent on rainfall patterns with most parts of Uganda experiencing bimodal rainfall except Karamoja [9]. There is a dry season from December to February before the first rainy season that starts in March and ends in June. There is also a second dry season from July to mid-August before the second rainy season that runs from mid-August to November. This allows for two cropping seasons [10]. The prices of seasonal crops typically peak just before the harvest, when supplies are scarce, and drop substantially immediately after harvest [11]. The prices of perishable foods such as fruits and vegetables show particularly high seasonality [12]. Fruits and vegetables are scarce during the dry seasons and as such cost more in such seasons [7]. Consumers substitute between foods according to price fluctuations [13]. Thus, measuring food prices quarterly and at the market level, instead of national annual measures, may better indicate the effect of prices on food choices [12]. Seasonal prices of foods can be obtained from local retailers, as it is the retailers that sell to the end consumers [6].

There is an urgent need to focus on the food intake of the poorest households if developing countries such as Uganda are to meet nutritional targets [14]. However, the least-cost staple food sources of nutrients and their nutrient compositions have not been established. This study aimed at establishing the nutritional composition of least-cost sources of nutrients in selected Eastern Uganda districts (Kamuli, Buyende and Pallisa) across the cropping seasons. Eastern Uganda was considered because it is the poorest region in Uganda [15]. The poverty rate in Eastern Uganda (24.5%) is significantly higher than the national rate [16]. The results of this study can help nutritionists give appropriate dietary counselling based on locally available and affordable sources.

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MATERIALS AND METHODS

Identification of least expensive available sources of different nutrients

The least-cost sources of energy, protein, iron and zinc were determined by a mini-survey following the guidelines of the World Food Programme (WFP) Vulnerability Analysis and Mapping (VAM) [17] Market Analysis Tool. Seasonal prices, seasonal availability and units of measurement of foods were obtained from retailers in local markets. Retailers in local markets usually reveal the food prices that the most vulnerable households are paying across seasons [6]. This data was used to determine the least-cost sources of energy, protein, iron and zinc.

Determination of sample size

According to the WFP VAM [17] Market Analysis Tool, a coverage ratio of at least 25% of the total markets in an area is sufficient to provide a picture that is representative of the local markets the target population uses. Markets were considered at sub-county level. The minimum number of markets to be visited for a 25% coverage ratio was calculated as follows:

- Kamuli = 25/100*20 markets = 5 markets
- Buyende = 25/100*7 markets = 1.75 markets
- Pallisa = 25/100*21 markets = 5.25 markets

Six markets were visited in Kamuli, three in Buyende and six in Pallisa districts thus meeting the Market Analysis Tool recommendation. The markets were randomly selected. All food retailers in the selected markets were visited. A total of 268 retailers were visited (Kamuli = 118, Buyende = 52 and Pallisa = 98).

Selection of least-expensive sources

The prices and availability of common foods in Kamuli, Buyende and Pallisa districts were collected from the retailers. For foods that are sold as different varieties, the cheaper varieties were considered. The least-cost sources of target nutrients were selected using nutrient cost values. The cost per 1000kcal of energy, 1g of protein, 1mg of iron and 1mg of zinc for available foods were calculated using the HarvestPlus food composition tables by Hotz *et al.* [18]. The foods with the five lowest nutrient costs were selected as the least expensive sources.

Preparation of food samples for analysis

Selected least expensive foods were purchased from local markets in Pallisa, Kamuli and Buyende districts. The foods were washed, thinly sliced to 4 mm, dried

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in an air drier at 60°C for 24 hours [19], and separately milled into flours. The flours were stored in airtight containers and kept out of the light before analysis [20].

Determination of gross energy, proximate and mineral content

Moisture content, protein, ash, and crude fat contents were determined using standard AOAC methods [21]. Moisture content was determined using the Air Oven Method, AOAC Method No. 925.10 using an air-forced laboratory oven (MRC Model: DFO-150). Ash was determined using AOAC method 923.03 using a laboratory chamber furnace (Carbolite™ CWF 1300). Crude fat was determined using the Soxhlet method, AOAC Method 922.06 using a Tecator 1043 Soxtec System. Protein content was determined based on the Kjeldahl method, AOAC Method No. 920.87 using a Kjeltec™ 8200 Auto Distillation Unit. Jones [22] nitrogen-to-protein factors were used to convert nitrogen content to protein content (Table 1).

Gross energy was determined by the combustion of a sample in a bomb calorimeter [23]. Sugars and starch were determined using the phenol–sulphuric acid method [24]. Dietary fiber was determined gravimetrically using acid detergent fibre reagent [25]. Iron and zinc were determined using an Atomic Absorption Spectrophotometer [21].

Statistical data analysis

The average prices of available foods per season were calculated using Microsoft Excel 2016. The prices obtained in Uganda shillings (UGX) were converted to USD using a rate of 1 USD = 3775.25 UGX). Means and standard deviations were derived for the nutritional properties using IBM® SPSS® Statistics (Version 26). One-way Analysis of Variance (ANOVA) was used to determine the significant differences among means generated for the nutritional properties of selected foods. Tukey's test was used to separate means. Differences in means were considered statistically significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Least-cost sources of energy, protein, zinc and Iron

The least-cost foods, their availabilities, prices and respective nutrient costs for the target nutrients are presented in Table 2. There were two common bean varieties namely *Kanyebwa* and *Nambale* of which *Nambale* was cheaper and therefore considered for this study. For sweet potatoes, white-fleshed sweet potatoes were cheaper and more available and were thus considered. For sorghum and

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groundnuts, the *seso* and red beauty types, respectively, which are commonly consumed at the household level, were considered.

The cost of the commonly available foods varied significantly in all four seasons (Table 2). For energy, iron and zinc the five foods with the lowest nutrient cost were selected. The least-cost foods in the first season were found to be the same as the least-cost foods in the second dry season. Similarly, the least-cost foods in the first rainy season were the same as the least-cost foods selected in the second rainy season. Foods of animal origin were not selected due to the high cost.

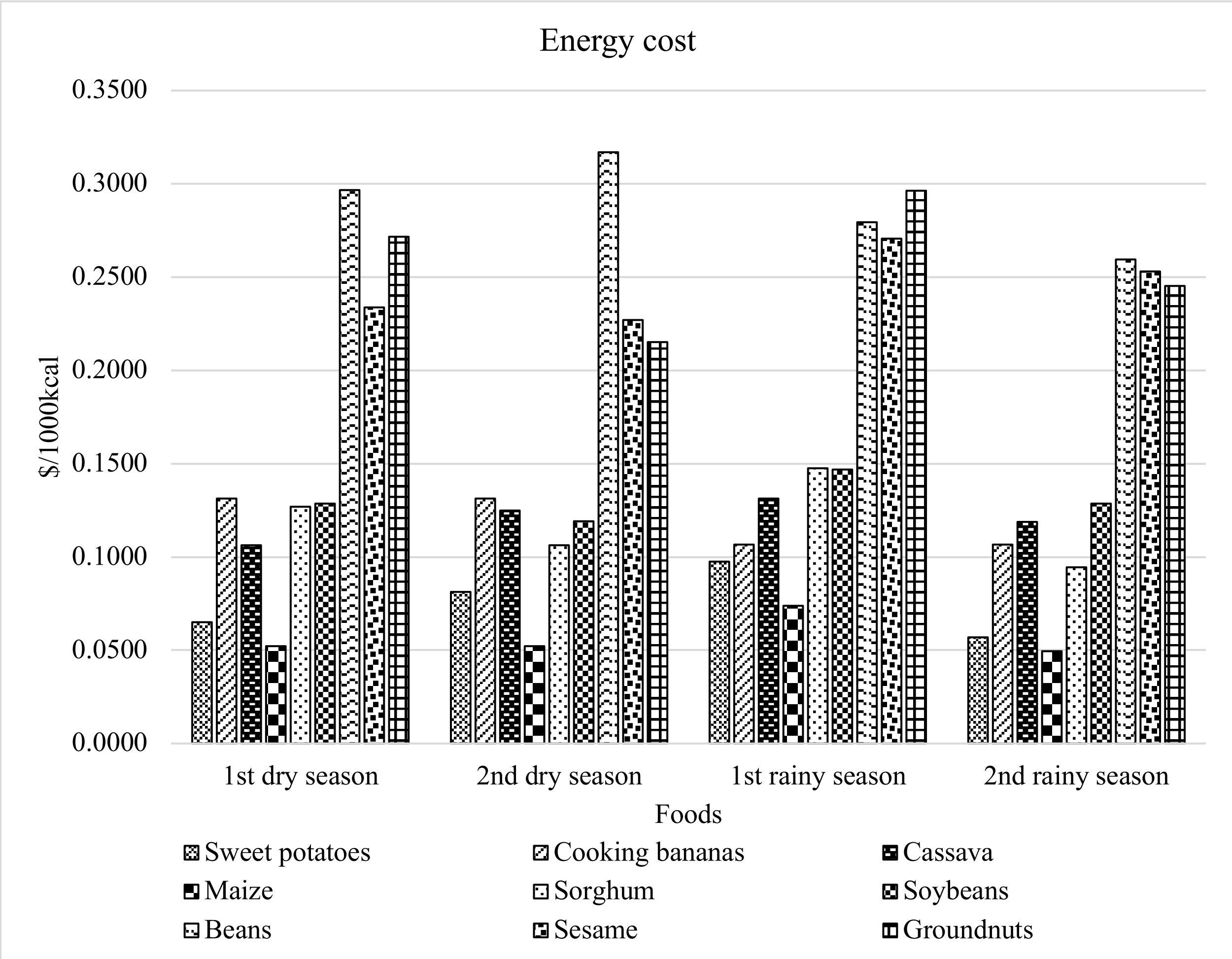

Figure 1: Energy cost of available foods

The least-cost sources of energy in the dry seasons were sweet potatoes, cassava, maize, sorghum and soybeans (Figure 1). In the rainy seasons, the least-cost sources of energy were sweet potatoes, cassava, maize, sorghum and cooking bananas. Cereals, roots and tubers are available across the cropping seasons and contribute 65% to the dietary energy in eastern Uganda [7].

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According to Vaclavik & Christian [26], proteins can be obtained from both animal and plant sources. The five least-cost protein sources in all seasons were maize, sorghum, soybeans, beans and groundnuts, which are all plant sources. Although cereals are not commonly considered as protein sources, they contain a significant quantity of protein that ranges between 8-12% on dry matter basis [27]. Cereals such as maize and sorghum have been reported to be limiting in the amino acid lysine, but this can be compensated for by combining them with pulses such as soybeans, groundnuts and beans, which are higher in lysine [27]. Soybeans and groundnuts have been utilized by Omueti *et al.* [28] to develop low-cost high-protein weaning food.

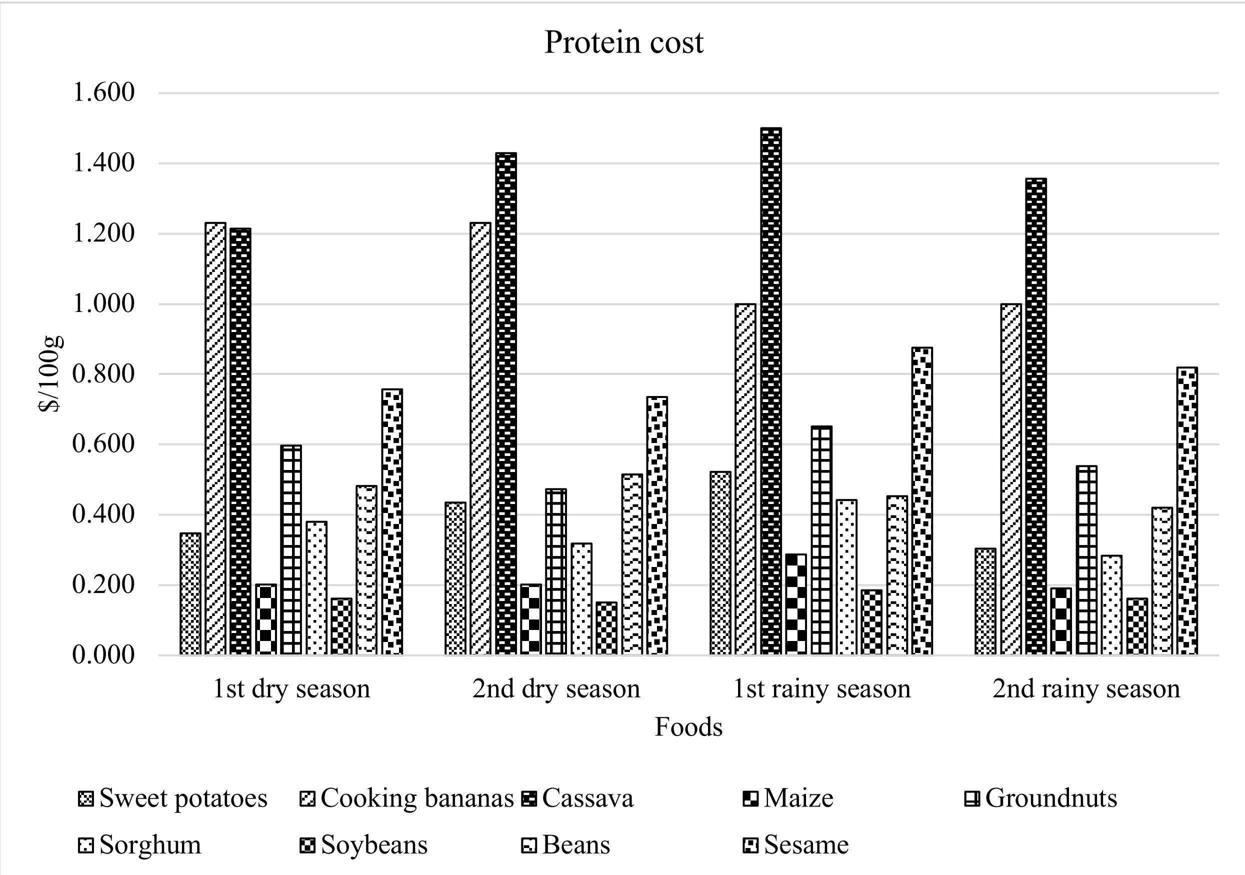

Figure 2: Protein cost of available foods

The five least-cost sources of iron and zinc in all seasons were sweet potatoes, maize, sorghum, soybeans and sesame (Figures 3 and 4). According to FAO & WHO [29], zinc and iron are low in cereals and tubers. Blending with legumes can slightly improve the iron content of the mixture. However, the bioavailability of non-heme iron sources is low. The availability of iron and zinc can be improved by

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reducing the phytate content of the mixture and including sources of animal protein [29].

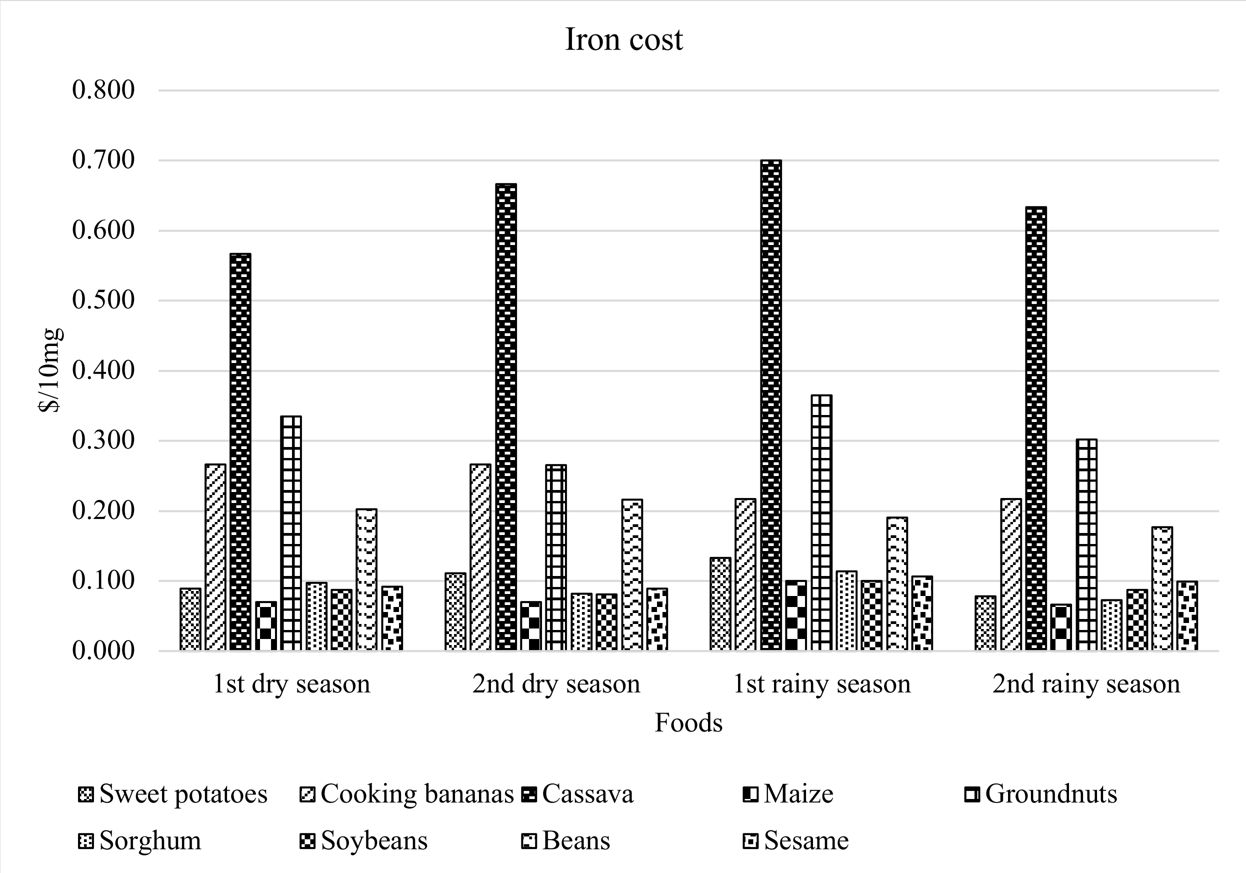

Figure 3: Iron cost of available foods

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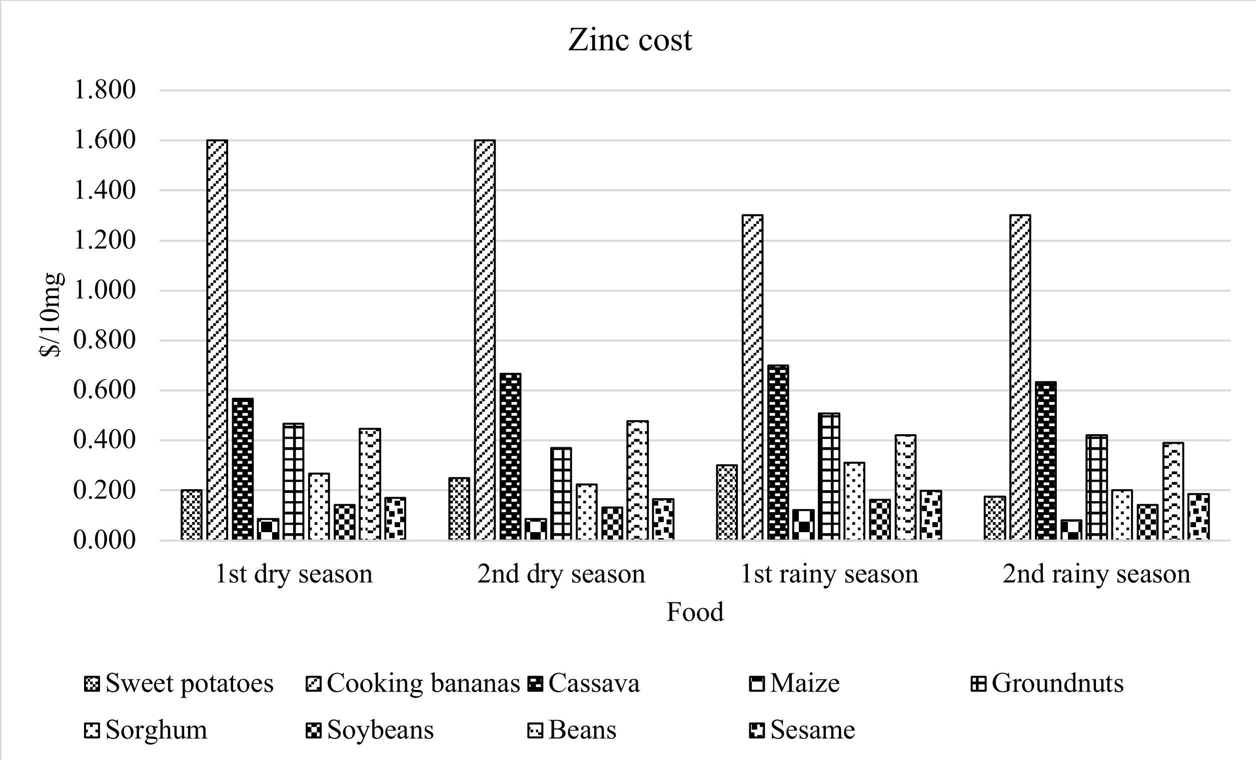

Figure 4: Zinc cost of available foods

Nutrient composition of least-cost sources of nutrients

The nutrient composition of the nine identified least-cost sources of nutrients is presented in Table 3. The gross energy ranged from 376.0 kcal/100g in cooking bananas to 797.2 kcal/100g in sesame. There were significant differences in the gross energy of the selected foods ($p \leq 0.05$). The gross energy values in this study for all foods were higher than the values reported by Hotz *et al.* [18]. The energy density of a formulated complementary food should be at least 4 kcal per gram (400 kcal/100g) on dry weight basis [27]. Except for cooking bananas, the foods in this study are good sources of energy for the development of complementary foods.

There were also significant differences in the proximate composition of the foods selected in this study (Table 3). Digestible carbohydrates are major energy sources and have an estimated energy value of 4 kcal/g [30]. The carbohydrate content of the least-cost foods selected in this study ranged from 8.1 g/100g in sesame to 98.3 g/100g in sweet potatoes. The carbohydrate content of sorghum and sweet potatoes were higher than the values reported by Hotz *et al.* [18]. On the other hand, the values reported for soybeans, maize, beans, sesame, groundnuts, cassava and cooking bananas were lower than the values reported by Bamigboye *et al.* [31], Hotz *et al.* [18], Manano *et al.* [32] and Nowakunda [33].

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Adequate protein consumption is essential for maintaining good health during normal development and aging [34]. The protein content of the foods selected in this study ranged from 3.4 g/100g in cassava to 40.7 g/100g in soybeans. The protein contents of beans, sesame, groundnuts and cassava were comparable to the values reported by Bamigboye *et al.* [31] and Hotz *et al.* [18]. However, the protein contents of soybeans and cooking bananas were higher than the values reported by Hotz *et al.* [18] and Nowakunda [33]. On the other hand, the protein content of sorghum, maize and sweet potato were lower than the values reported by Abamecha [35] and Hotz *et al.* [18]. Soybeans, groundnuts, beans, sesame, maize and sorghum had a protein content greater than 8g/100g and as such are potential protein sources for the nutrient-dense mixtures for complementary feeding [27].

Fat can be used to increase the energy density of complementary foods [27]. The crude fat content of the foods selected in this study ranged from 0.6 g/100g in sweet potatoes to 52.9 g/100g in sesame. The crude fat content of maize, sesame, beans, cassava and sweet potatoes were comparable to those reported by Abamecha [35] and Hotz *et al.* [18]. However, the crude fat content of soybeans, sorghum, groundnuts and cooking bananas were lower than the values reported by Abamecha [35] and Hotz *et al.* [18].

The fiber content of the least-cost foods selected in this study ranged from 1.4 g/100g in cooking bananas to 7.0 g/100g in soybeans. The fiber contents reported in this study were lower than the values reported by Bamigboye *et al.* [31], Hotz *et al.* [18] and Manano *et al.* [32]. Diets that are high in fiber have been associated with several health benefits such as preventing constipation and diverticulosis as well as improved glucose tolerance [31]. However, for formulated complementary food, the fiber content should not exceed 5 g/100g. Fiber can decrease appetite, reduce the energy density of the formulated food and affect the efficiency of absorption of nutrients [27]. As such, soybeans should be used in combination with foods that have a low fibre content. The fibre content of soybeans can also be reduced by dehulling [36].

The ash content consists of the inorganic residue that remains after ignition of organic matter in a food sample. This inorganic residue consists mainly of the minerals present in the food sample [37]. The ash content of the least-cost foods selected in this study ranged from 1.4 g/100g in maize to 5.7 g/100g in soybeans. Soybeans, sesame and beans had significantly higher ash contents than the other foods. The ash contents of maize, sesame, cassava and cooking bananas were

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consistent with the values reported by Abamecha [35], Bamigboye *et al.* [31], Manano *et al.* [32] and Nowakunda [33]. However, the ash contents of soybeans, sorghum, groundnuts and beans were higher than the values reported by Abamecha [35]. The ash content of sweet potatoes was higher than the value reported by Eke-Ejiofor & Mbaka [38].

There were significant differences in the iron and zinc content of the least-cost foods in this study. Iron serves various important functions in the body such as transporting oxygen from the lungs to the tissues via red blood cell hemoglobin [29]. The iron content of the least-cost foods selected in this study ranged from 0.1 mg/100g in cassava, cooking bananas and sweet potatoes to 6.6 mg/100g in soybeans. The iron contents of soybeans and sorghum were comparable to the values that were reported by Abamecha [35] and Hotz *et al.* [18]. However, the iron content of maize, beans, sesame, cassava, cooking bananas and sweet potatoes were lower than the values reported by Hotz *et al.* [18]. The iron content of groundnuts was higher than the values reported by Hotz *et al.* [18]. The iron contents of soybeans, sorghum, maize, sesame, groundnuts and beans are considered significant for children under 10 years as they meet 5% of the daily RNI [29,39].

Zinc is a vital component of over 300 enzymes in the body and is also essential for the functioning of the immune system [29]. The zinc content of the least-cost foods selected in this study ranged from 0.1 mg/100g in cassava and sweet potatoes to 5.1 mg/100g in sesame. The zinc content of sesame was comparable to the value reported by Bamigboye *et al.* [31]. The zinc contents of maize and beans were comparable to the values that were reported by Hotz *et al.* [18]. However, the zinc contents of sorghum and groundnuts were higher than and those of soybeans, cassava, sesame, cooking bananas and sweet potatoes lower than the values reported by Hotz *et al.* [18]. The zinc contents of soybeans, sorghum, maize, sesame, cooking bananas, groundnuts and beans are considered significant for children under 10 years as they meet 5% of the daily RNI [29,39]. The differences in the values obtained in this study and those in the literature used for comparison can be attributed to differences in factors such as climate, soil and plant varieties [40].

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

This study aimed at establishing the nutritional composition of least-cost staple food sources of nutrients in eastern Uganda across the cropping seasons. The least-cost sources of energy in the dry seasons were sweet potatoes, cassava, maize, sorghum and soybeans. In the rainy seasons, the least-cost sources of energy were sweet potatoes, cassava, maize, sorghum and cooking bananas. Seasonality did not influence the least cost sources of, protein, iron and zinc. The five least-cost protein sources in all seasons were maize, sorghum, soybeans, beans and groundnuts. The five least-cost sources of iron and zinc in all seasons were sweet potatoes, maize, sorghum, soybeans and sesame. The nutrition composition of least-cost foods in the dry seasons and rainy seasons indicates that they can be used to formulate low-cost nutrient-dense mixtures. Further studies should investigate the potential of these foods to constitute acceptable nutrient-dense mixtures for complementary feeding and any resulting nutrient gaps.

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Table 1: Jones conversion factors

Food	Conversion factor
Soybeans	5.71
Sorghum	6.25
Maize	6.25
Sesame	5.30
Groundnuts	5.46
Cassava	6.25
Cooking bananas	6.25
Sweet potatoes	6.25
Beans	6.25

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Table 2: Cost of commonly available foods in Kamuli, Buyende and Pallisa districts across the cropping seasons

	Availability in different seasons (H = High; M = Moderate; L = Low)				Cost ($/kg)			
	Rainy		Dry					
Food	**1**	**2**	**1**	**2**	**1st dry season**	**1st rainy season**	**2nd dry season**	**2nd rainy season**
Sweet potatoes	M	H	H	M	0.08 ± 0.02^{a}	0.12 ± 0.08^{a}	0.10 ± 0.08^{a}	0.07 ± 0.03^{a}
Cooking bananas	H	M	L	L	0.16 ± 0.11^{ab}	0.13 ± 0.09^{a}	0.16 ± 0.09^{ab}	0.13 ± 0.07^{ab}
Cassava	M	M	H	M	0.17 ± 0.02^{ab}	0.21 ± 0.03^{ab}	0.20 ± 0.00^{ab}	0.19 ± 0.01^{ab}
Maize	M	M	M	H	0.19 ± 0.02^{ab}	0.27 ± 0.02^{ab}	0.19 ± 0.02^{ab}	0.18 ± 0.02^{ab}
Sorghum	M	M	M	M	0.43 ± 0.07^{bc}	0.50 ± 0.11^{bc}	0.36 ± 0.10^{ab}	0.32 ± 0.10^{ab}
Soybeans	M	M	M	M	0.56 ± 0.15^{c}	0.64 ± 0.12^{cd}	0.52 ± 0.10^{b}	0.56 ± 0.09^{bc}
Beans	H	H	H	H	1.03 ± 0.05^{d}	0.97 ± 0.24^{d}	1.10 ± 0.14^{c}	0.90 ± 0.33^{c}
Sesame	M	M	M	M	1.34 ± 0.14^{e}	1.55 ± 0.11^{e}	1.30 ± 0.24^{c}	1.45 ± 0.32^{d}
Groundnuts	M	M	M	H	1.54 ± 0.16^{e}	1.68 ± 0.18^{e}	1.22 ± 0.18^{c}	1.39 ± 0.20^{d}

Costs are means ± standard deviation (n=3 districts). Means in each column with different superscripts are significantly different ($P \le 0.05$)

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Table 3: Gross energy and nutrient composition of least-cost foods from Eastern Uganda per 100g of dry matter

Food	Energy (Kcals)	Sugars (g)	Starch (g)	Protein (g)	Crude fat (g)	Fiber (g)	Ash (g)	Iron (mg)	Zinc (mg)
Soybeans	555.2 ± 9.62^{ab}	9.7 ± 0.34^{ab}	7.6 ± 1.54^{ab}	40.7 ± 4.58^{d}	18.0 ± 2.01^{b}	7.0 ± 0.32^{d}	5.7 ± 0.42^{d}	6.6 ± 0.40^{cd}	1.6 ± 0.24^{a}
Sorghum	431.6 ± 20.16^{a}	4.0 ± 0.39^{ab}	71.2 ± 22.34^{c}	9.7 ± 0.32^{a}	2.8 ± 0.14^{a}	2.6 ± 0.69^{ab}	2.1 ± 0.24^{ab}	4.4 ± 0.86^{b}	2.4 ± 0.47^{ab}
Maize	457.4 ± 27.06^{a}	2.2 ± 0.21^{a}	64.4 ± 8.82^{c}	9.3 ± 2.26^{a}	5.4 ± 0.73^{a}	1.8 ± 0.19^{a}	1.4 ± 0.25^{a}	1.1 ± 0.13^{a}	2.8 ± 0.40^{ab}
Sesame	797.2 ± 116.84^{c}	4.2 ± 0.57^{ab}	3.9 ± 2.60^{a}	17.2 ± 1.75^{b}	52.9 ± 3.82^{d}	3.5 ± 0.65^{bc}	6.3 ± 0.59^{d}	6.2 ± 0.57^{cd}	5.1 ± 1.37^{b}
Groundnuts	723.7 ± 31.69^{bc}	7.0 ± 0.56^{ab}	6.4 ± 3.04^{a}	29.5 ± 2.57^{c}	45.6 ± 2.37^{c}	4.3 ± 0.95^{c}	2.5 ± 0.10^{ab}	7.0 ± 0.82^{d}	4.9 ± 1.51^{b}
Cassava	534.3 ± 166.06^{ab}	3.7 ± 0.29^{ab}	67.9 ± 9.53^{c}	3.4 ± 1.59^{a}	0.7 ± 0.15^{a}	1.9 ± 0.47^{ab}	2.2 ± 0.41^{ab}	0.1 ± 0.02^{a}	0.1 ± 0.00^{a}
Cooking bananas	376.0 ± 14.07^{a}	10.4 ± 8.49^{ab}	71.0 ± 10.03^{c}	7.8 ± 0.54^{a}	0.7 ± 0.46^{a}	1.4 ± 0.27^{a}	3.9 ± 0.32^{c}	0.1 ± 0.00^{a}	1.5 ± 0.68^{a}
Sweet potatoes	442.6 ± 16.47^{a}	11.5 ± 1.22^{b}	86.8 ± 10.75^{c}	5.8 ± 1.98^{a}	0.6 ± 0.37^{a}	2.1 ± 0.46^{ab}	2.9 ± 0.19^{bc}	0.1 ± 0.01^{a}	0.1 ± 0.00^{a}
Beans	457.1 ± 10.24^{a}	7.5 ± 0.97^{ab}	35.4 ± 2.65^{b}	22.6 ± 4.10^{bc}	1.4 ± 0.43^{a}	4.6 ± 0.77^{c}	5.2 ± 0.62^{d}	4.9 ± 1.15^{bc}	2.8 ± 0.51^{ab}

Values are means ± standard deviation of triplicate determinations. Means in each column with different superscripts are significantly different ($P \leq 0.05$)

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